Before the
FEDERAL COMMUNICATIONS COMMISSION
Washington, D.C. 20554

In the Matter of	)	
Unlicensed Use of the 6 GHz Band	)	ET Docket No. 18-295
Expanding Flexible Use in Mid-Band Spectrum between 3.7 and 24 GHz	)	GN Docket No. 17-183

COMMENTS OF HEWLETT PACKARD ENTERPRISE COMPANY

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INTRODUCTION AND SUMMARY

Hewlett Packard Enterprise ("HPE") applauds the Commission's decision to issue a Notice of Proposed Rulemaking ("NPRM") proposing to open the 6 GHz band (5.925 GHz to 7.125 GHz) to unlicensed technologies.[1] The NPRM demonstrates the Commission's careful consideration of comments submitted by a wide range of parties in response to the Commission's Notice of Inquiry regarding expanded use of mid-band spectrum.[2] In particular, the Commission has correctly recognized the need to address the "explosive demand" for unlicensed spectrum and the central role unlicensed technology plays in expanding connectivity for all Americans.[3] HPE further commends the Commission for proposing to adopt Automated Frequency Coordination ("AFC") as an innovative yet simple way to use existing license databases to enable efficient unlicensed use and robust protection for licensees.

HPE is one of the world's largest providers of managed wireless local area network ("WLAN") infrastructure and is a global leader in the Wi-Fi equipment marketplace. HPE's Aruba business unit ships millions of Wi-Fi access points ("APs") every year and is one of the world's largest providers of enterprise WLAN equipment, representing almost 14 percent of the global market for such devices.[4] HPE provides mission-critical equipment to a broad set of industries,

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1 *Unlicensed Use of the 6 GHz Band*, Notice of Proposed Rulemaking, FCC No. 18-147, ET Docket 18-295 (rel. Oct. 24, 2018) ("6 GHz NPRM").

2 *Expanding Flexible Use in Mid-Band Spectrum Between 3.7 and 24 GHz*, Notice of Inquiry, FCC No. 17-104, GN Docket No. 17-183 (rel. Aug. 3, 2017); *see also* Comments of Hewlett Packard Enterprise Company, GN Docket No. 17-183 (filed Oct. 2, 2017); Comments of the Wi-Fi Alliance, GN Docket No. 17-183 (filed Oct. 2, 2017); Comments of Broadcom, Ltd., GN Docket No. 17-183 (filed Oct. 2, 2017); Reply Comments of Apple Inc., Broadcom Ltd., et. al., GN Docket No. 17-183 (filed Nov. 15, 2017).

3 *See* 6 GHz NPRM at ¶ 3.

4 International Data Corporation, *Worldwide Quarterly WLAN Tracker* (Dec. 2018), https://www.idc.com/getdoc.jsp?containerId=prUS44521718.

including hospitals, hotels, universities, airports, military and defense agencies, and other government agencies at the national, state, and local levels. Additionally, HPE supports mobile operators seeking to expand their networks with unlicensed APs, servers, storage, software, and services to help power some of the world's largest mobile core networks. This marketplace position gives HPE a deep understanding of unlicensed technology growth and use, how FCC rules impact real-world engineering decisions, and how spectrum policy can advance or restrict innovation.

In this proceeding, HPE continues to partner with a broad group of equipment manufacturers, software makers, and internet service companies that work together to make the 6 GHz band available for unlicensed use ("the RLAN Group"). HPE supports the comprehensive comments filed by this group and the technical declarations appended to those comments.[5] We submit these individual comments to highlight issues where HPE has specialized insight due to our position as a manufacturer providing enterprise and commercial WLAN equipment.

The 6 GHz band is already occupied by licensees providing important services. Under the FCC's proposal, unlicensed users must avoid causing harmful interference to these licensees, consistent with the time-tested Part 15 rules.[6] As the Commission notes in the NPRM, incumbent licensees and the technology industry supporting unlicensed use have worked together on the future use of the 6 GHz band and have submitted materials to the Commission showing "a good-faith effort to work toward finding areas of potential agreement on accommodating shared use."[7] This work has yielded wide areas of agreement, greatly narrowing the issues that still need to be addressed

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5 Comments of Apple Inc., Broadcom Inc., Cisco Systems, Inc., Facebook, Inc., Google LLC, Hewlett Packard Enterprise, Intel Corporation, Marvell Semiconductor, Inc., Microsoft Corporation, Qualcomm Incorporated, and Ruckus Networks, an Arris Company, ET Docket No. 18-295, GN Docket No. 17-183 (filed Feb. 15, 2019) ("RLAN Group Comments").

6 6 GHz NPRM at ¶ 8; 47 C.F.R. § 15.5(b).

7 6 GHz NPRM at ¶ 17.

in this proceeding. Most importantly, it is now clear that 6 GHz radio local area networks ("RLANs") do not pose a real-world risk of harmful interference to Fixed Service ("FS") links in the vast majority of situations. Only in the unusual corner case where an RLAN is operating in or near the main beam of an FS link is there even a potential risk of harmful interference. To address this corner case, for outdoor standard-power access points, the Fixed Wireless Communications Coalition ("FWCC") and the RLAN Group agree on the use of an AFC system.[8]

These comments therefore focus on three areas that remain unresolved: (1) operation of low-power indoor ("LPI") operations throughout the 6 GHz band, (2) establishment of AFC operational rules and interference protection criteria that protect incumbents without eliminating flexibility and innovation, and (3) adoption of technical rules that will enable the successful deployment of managed networks, including allowing for effective operation of directional antennas and client device control signals.

I. THE COMMISSION HAS CORRECTLY RECOGNIZED THAT IT MUST ACT NOW TO ALLOW UNLICENSED TECHNOLOGIES IN THE 6 GHZ BAND TO ADDRESS DEMAND.

Wi-Fi is now critical to many sectors of the U.S. economy, powering not only connectivity for homes and enterprises, but also transportation, healthcare, education, and military communications. Unlicensed technologies, including Wi-Fi, have changed the way Americans live and work and have generated enormous benefits for our nation.[9] Wi-Fi is no longer simply an amenity that improves customer experiences and connectivity: it is now a foundational and

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8 *See* Letter from Cheng-yi Liu to Marlene Dortch, GN Docket No. 17-183, at 14-15 (filed Jul. 17, 2018; *see also* Letter from the Radio Local Area Network Group to Marlene Dortch, GN Docket No. 17-183, at 3 (filed Jun. 12, 2018).

9 Raul Katz & Fernando Callorda, *The Economic Value of Wi-Fi: A Global View (2018 and 2023)*, Telecom Advisory Services, 33-34 (Oct. 2018), https://www.Wi-Fi.org/downloads-registered-guest/Economic%2BValue%2Bof%2BWi-Fi%2B2018.pdf/35675.

necessary tool for commerce that connects U.S. businesses to one another and to the rest of the world. Wi-Fi, z-wave, Bluetooth, and RFID are integrated into supply chain management and depend on unlicensed spectrum to coordinate the movement of products and cargo. Container terminals, distribution centers, and warehouses in the U.S. run on Wi-Fi networks that enable machines, vehicles, and people to coordinate their work. Unlicensed services have transformed the airline, healthcare, and educational sectors, both in the way consumers interact with them and the way they organize internal operations.[10]

The forthcoming transition to 5G networks will accelerate the use of, and demand for, unlicensed spectrum, because both Wi-Fi and 5G NR-U (new radio - unlicensed) will be critical components of 5G networks. The new Release 15 and 16 specifications for 5G from 3GPP include, for the first time, the ability to directly manage "non-3GPP" radio systems such as Wi-Fi on a nearly equal footing as 5G NR.[11] Both private enterprise and carrier Wi-Fi networks will be managed by the same control interfaces as 5G NR, and the 5G next-generation core ("NGC") even adopts a converged security architecture enabling encryption keys for both licensed radio access networks ("RANs") and Wi-Fi networks to be derived from common keying material. It is well known that today, Wi-Fi carries over 70% of all data traffic originating on mobile devices.[12] In effect, the operators that drive 3GPP standards development are embedding today's offload reality into the

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[10] *See, e.g.*, *Healthcare*, Aruba: a Hewlett Packard Enterprise Company (last visited Jan. 30, 2019), https://www.arubanetworks.com/solutions/healthcare/.

[11] *See* 3GPP, *Release 16*, The Mobile Broadband Standard, (Jul. 16, 2018), http://www.3gpp.org/release-16; *see also* 3GPP, *Release 15*, The Mobile Broadband Standard, (Jan. 25, 2019), http://www.3gpp.org/release-15.

[12] Claus Hetting, *New numbers: Wi-Fi share of US mobile data traffic lingers at around 75% in Q2*, Wi-Fi Now (Aug. 16, 2018), https://wifinowevents.com/news-and-blog/new-numbers-wi-fi-share-of-us-mobile-traffic-lingers-at-around-75/.

fabric of the 5G system by enabling Wi-Fi RAN layers to be directly controlled and integrated with licensed RAN layers.

Additionally, Wi-Fi calling is exploding in popularity and use in the U.S. and around the globe. All four major U.S. cellular phone carriers offer Wi-Fi calling, and emerging networks such as Google Fi and Republic Wireless prioritize Wi-Fi calls.[13] In addition, over 90 percent of countries enjoy Wi-Fi calling support from the four major U.S. carriers, and 84 global carriers (17 of which serve the U.S.) support Wi-Fi calling.[14] Wi-Fi calling demonstrates that unlicensed spectrum creates value for consumers, businesses, and carriers themselves (AT&T has monetized the value of unlicensed spectrum by charging for Wi-Fi-originated calls from the U.S. to international numbers).[15]

Troublingly, and as the Commission has recognized, the amount of spectrum currently authorized for unlicensed use is insufficient to meet current, much less future, demand for Wi-Fi and other unlicensed uses.[16] Evidence for this conclusion abounds. One of the strongest examples is that the vast majority of enterprise customers deploying gigabit-capable 802.11ac access points intentionally de-feature those products to use 40 MHz instead of 80 MHz channels. Cisco recently

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[13] Lynn La, *Everything you need to know about Wi-Fi calling*, CNET (Nov. 28, 2018), https://www.cnet.com/news/what-is-wifi-calling-tmobile-verizon-att-google-fi-sprint-setup-faq/.

[14] *See Wi-Fi Calling: More access in more places*, AT&T (last visited Jan. 30, 2019), https://www.att.com/shop/wireless/features/wifi-calling.html ("Wi-Fi Calling"); *see also FAQs about Wi-Fi calling*, Sprint (last visited Jan. 30, 2019), https://www.sprint.com/en/support/solutions/services/faqs-about-wi-fi-calling.html; *see also Wireless carrier support and features for iPhone in the United States and Canada*, Apple Support (last visited Jan. 30, 2019), https://support.apple.com/en-us/HT204039#usa.

[15] Wi-Fi Calling.

[16] *See, e.g.,* 6 GHz NPRM, Statement of Commissioner Rosenworcel (noting the current use of unlicensed bands by over 9 billion devices and the explosive projected growth of new connected devices in the next decade).

published an anonymized analysis of over 30,000 gigabit-capable configurations which showed that 89% were using 40 MHz or even 20 MHz channel widths, and only 11% were using 80 MHz. This decision is an intentional tradeoff on busy networks to reduce co-channel traffic by distributing load across a larger number of channels at the cost of a 50% reduction in performance.[17]

The Commission is therefore correct to act now and to adopt rules that will maximize the potential for Wi-Fi expansion in the 6 GHz band. Quick action is critical, because if the Commission acts soon, the availability of the 6 GHz band for Wi-Fi will coincide with the launch of the new Wi-Fi 6 protocol, using the IEEE 802.11ax standard to deliver operator-grade service—up to 4.8 Gbps at the physical layer—by using Orthogonal Frequency Division Multiple Access ("OFDMA") scheduling to reduce latency.[18]

The FCC's effort to expand Wi-Fi and unlicensed technologies in the 6 GHz band also advances key national policy priorities of both Congress and the Executive Branch. In 2018, the White House released a landmark Presidential Memorandum on "Developing a Sustainable Spectrum Strategy for America's Future," recognizing that American companies and institutions rely on wireless connections and specifically requesting the development of a National Spectrum Strategy that promotes efficient spectrum use through sharing tools.[19] Furthermore, Congress directed the Commission and NTIA to identify unlicensed spectrum below 8 GHz.[20] And the Commission has

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[17] Brian Hart el. al., *Recommended Direction for EHT*, Cisco, (Sept. 9, 2018), https://mentor.ieee.org/802.11/dcn/18/11-18-1549-00-0eht-candidate-technology-review.pptx.

[18] Cisco, *IEEE 802.11ax: The Sixth Generation of Wi-Fi* at 1, 8 (Jun. 2018) ("The Sixth Generation of Wi-Fi"), https://www.cisco.com/c/dam/en/us/products/collateral/wireless/white-paper-c11-740788.pdf.

[19] *See* Trump, Donald J., *Presidential Memorandum on Developing a Sustainable Spectrum Strategy for America's Future*, Whitehouse.gov (Oct. 25, 2018), https://www.whitehouse.gov/presidential-actions/presidential-memorandum-developing-sustainable-spectrum-strategy-americas-future/.

[20] *See* MOBILE NOW Act, Pub. L. No. 115-141, § 603(a)(1), 132 Stat. 348, 1098 (2018) (codified as amended at 47 U.S.C. § 1502).

specifically recognized the importance of unlicensed technologies in facilitating U.S. leadership in 5G networks, as explained in the FCC's 5G FAST Plan.[21] The 6 GHz band represents the best way to achieve these goals, and HPE thanks the Commission staff for their work thus far on this innovative plan for the 6 GHz band.

In support of these national goals, HPE is already hard at work designing our first set of 6 GHz products and is committed to rapidly deploying devices if the Commission adopts a workable set of rules for the band. As discussed below, if the Commission authorizes low-power indoor operations in all four 6 GHz sub-bands, allows for flexible implementation of AFC systems, and includes technical rules conducive to managed use cases, HPE hopes to ship products for use in the 6 GHz band in 2021, to coincide with the second wave of Wi-Fi 6 deployment.

II. LOW-POWER INDOOR OPERATIONS ARE VITAL TO THE SUCCESS OF THE 6 GHZ BAND AND CAN SAFELY AND EFFECTIVELY SHARE WITH LICENSED INCUMBENT SERVICES.

Low-power indoor ("LPI") operations will be essential to the success and long-term utility of the 6 GHz band. This class of devices represents the most efficient way to put the band to work for a vast range of industries and consumers. We commend the Commission for recognizing the value of LPI operations and moving to make 6 GHz spectrum available for LPI use. However, allowing LPI operations only in U-NII-6 and -8 provides insufficient spectrum to incentivize and enable the scope of operations the Commission envisions for this band. To achieve a success in the 6 GHz band, the Commission should authorize LPI access points to operate across all four sub-bands and should permit very-low-power ("VLP") operations at 14 dBm both indoors and outdoors. As described below, and in more detail in the RLAN Group Comments, doing so will not

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21 *See The FCC's 5G FAST Plan,* FCC at 1, https://docs.fcc.gov/public/attachments/DOC-354326A1.pdf.

cause harmful interference to licensed services in the band. A realistic assessment of LPI use cases demonstrates that the Commission can and should authorize low-power indoor unlicensed use throughout the 6 GHz band.

A. Restricting LPI to a Minority of the 6 GHz Band Would Undermine the Tremendous Potential Benefits the Commission Seeks to Create.

LPI operations are fundamental to major 6 GHz use cases. In fact, LPI devices will likely represent the majority of the market for access points in the band. Indoor devices operating at 24 dBm (250 milliwatt) conducted power limits support the majority of unlicensed use cases in other unlicensed bands today, and HPE expects LPI operations to be the leading mode of deployment in the 6 GHz band.[22] Sectors such as healthcare, military, and manufacturing currently rely heavily on applications that operate indoors, at the low power levels proposed in the NPRM, and would benefit tremendously from being able to access the full 6 GHz band soon. The Commission has likewise recognized that LPI devices will be critical to support connectivity for enterprise and consumer applications.[23]

In fact, virtually all indoor APs shipped by Aruba and other enterprise manufacturers are only capable of a maximum EIRP of 30 dBm or less today, which the Commission wisely proposes as the radiated power limit for LPI devices. For example, a review of the data sheet for the new Aruba AP-345 4x4 802.11ac Wave 2 access point shows a peak per-chain power of 18 dBm for the lowest data rate, and just 12 dBm for the highest 256 QAM rate. The internal antennas have a measured peak gain of 5.6 dBi. Combining four radio chains yields a total EIRP of 29.6 dBm.

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22 For example, the Cisco 2018 VNI predicts that globally, machine-to-machine modules will account for 51% (14.6 billion) of all networked devices by 2022, compared to only 34% in 2017. *See VNI Forecast Highlights Tool, Device Growth/Traffic Profiles*, Cisco (last visited Jan. 30, 2019), https://www.cisco.com/c/m/en_us/solutions/service-provider/vni-forecast-highlights.html.

23 *See* 6 GHz NPRM at ¶ 59.

Considering the exhaustive analysis of the safety of LPI in the RLAN Group filing[24] and its compatibility with existing deployments, there is no reason to delay making LPI available across all four sub-bands.

Despite the Commission's recognition that low-power indoor operations are essential, the NPRM proposes to allow LPI operations in only 350 megahertz of spectrum in the U-NII-6 and -8 sub-bands.[25] This proposal is inconsistent with the Commission's central goals in this proceeding: to meet the explosive demand for unlicensed spectrum, provide frequencies that will be complementary to new licensed 5G services, and to relieve the congestion consumers currently experience in the Wi-Fi bands.[26]

Providing only two sub-bands for LPI operations will undermine incentives for equipment manufacturers to invest in equipment production and deployment because the location of the two frequency ranges would significantly reduce the number and size of available channels. This arrangement would split available channels between the 100-megahertz-wide U-NII-6 sub-band and the 250-megahertz-wide U-NII-8 band, and would create a 575 MHz-wide gap between U-NII-3 and U-NII-6 for the several years necessary to complete work on AFC systems, posing difficult cost and complexity challenges for manufacturers like HPE.[27] Importantly, LPI devices would not be able to access channels that cross boundaries between the four sub-bands, resulting in even less actually usable spectrum than the theoretically available 350 megahertz contained in U-NII-6 and -8. This configuration would support *only one 160 MHz channel for LPI use* and would support a limited

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24 *See* RLAN Group Comments at 17-30.

25 6 GHz NPRM at ¶ 59.

26 *Id.* at ¶¶ 1, 2, and 4; *see also* 6 GHz NPRM, Statement of Commissioner Carr and 6 GHz NPRM, Statement of Commissioner Rosenworcel.

27 *See* 6 GHz NPRM at ¶ 21, band allocation table, describing the frequency divisions for the four 6 GHz sub-bands.

number of 40 and 80 megahertz channels. This arrangement would therefore prevent LPI devices from being able to access wider channel sizes that facilitate higher speeds using newer Wi-Fi protocols.[28] Manufacturers will limit investment in enabling wider channel sizes if those channels cannot operate in new bands. However, if the Commission authorizes LPI operations throughout the entire band, it would result in at least a six-fold increase in the number of available 160 MHz channels, thus creating a significant incentive for manufacturers to enable such channels.

A band plan diagram best conveys the dilemma that the NPRM poses to manufacturers as written. Figure 1 shows the currently approved IEEE band plan for the new 802.11ax Wi-Fi protocol. Under this plan, the Commission would impose large and unnecessary hardware costs on the U-NII-6 band that undermine the FCC's goals. There are only four usable 20 MHz channels, one usable 40 MHz channel, and zero gigabit-capable 80 MHz channels. As a hypothetical exercise, shifting the band plan over to align the U-NII-6 boundaries with the 20 MHz minimum channel raster used by Wi-Fi as shown in Figure 2 improves matters only marginally—only three usable 80 MHz channels would exist in the entire 6 GHz band for several years. As a multi-channel system, Wi-Fi needs more than three channels to operate regardless of the bandwidth, and this configuration would relegate our customers to de-featuring their WLANs to use narrow channels.

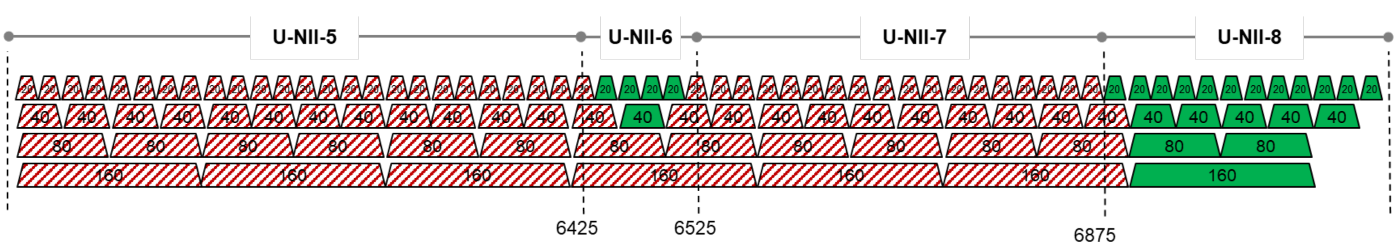

Figure 1: Approved IEEE 6 GHz Band Plan with 10 MHz Guard Bands on Both Ends

28 *See* The Sixth Generation of Wi-Fi.

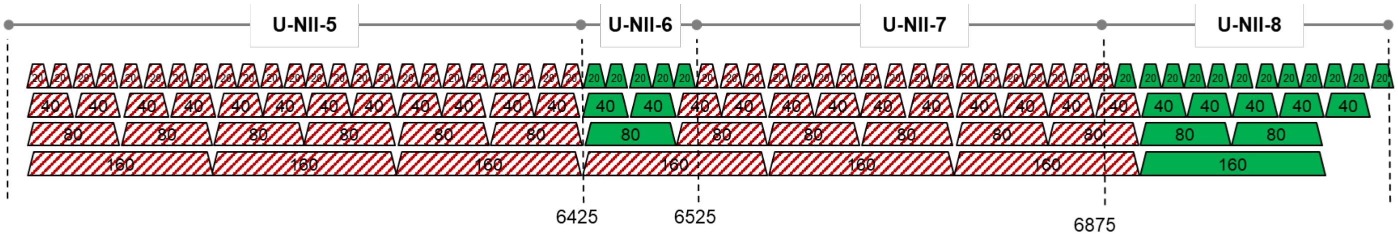

Figure 2: Illustrative 6 GHz Band Plan with 20 MHz Guard Band at 5.925 GHz

The likely result of the Commission's current proposal therefore would be to impair investment and deployment, especially for the several years expected until AFC-authorized operations can commence, denying consumers the very benefit the NPRM seeks to unlock. Many equipment makers will not invest to build the type of intensive use the Commission hopes to see with access to only 350 MHz of spectrum—broken into two noncontiguous and challenging fragments—for LPI operations. Based on experiences with database-authorized spectrum sharing in other bands, HPE predicts that development and certification of AFC systems will take a minimum of two years. In the 6 GHz band, original equipment manufacturers ("OEMs") are ready to develop LPI products now while they work on the AFC and are waiting only for the Commission to authorize use of sufficient spectrum in the band. The Commission should not prevent this.

A wait-and-see strategy with regard to wider LPI authority would have real and negative consequences for consumers and manufacturers beyond limiting performance. Equipment vendors must design devices for regulatory environments they know exist, not the ones they hope will exist. Manufacturers cannot afford bill-of-materials cost increases to include functionalities that will be inaccessible in the near-term. Put simply, HPE and other equipment makers cannot ship products designed for frequencies they aren't yet authorized to use. Presented with the band plan options above, manufacturers have no incentive to invest in, for example, wider-tuning front ends or more effective out-of-band-emissions filters, in order to "future proof" LPI equipment for eventual AFC-enabled operations in U-NII-5 and -7. Equipment makers may choose to only enable LPI devices to access U-NII-6 and -8. Such devices would not be field-upgradable to access U-NII-5 and -7 once the Commission finalizes the AFC framework, stranding customer investment and potentially stalling interest in the band.

Finally, limiting LPI to only two sub-bands would undermine the global harmonization of frequencies that has made other unlicensed bands so successful, causing market fragmentation and reduced investment. Based on our work in Europe, HPE believes that LPI operations will likely be authorized in the 6 GHz band by international jurisdictions in U-NII-5. The AFC control framework for standard-power APs eventually deployed in the U.S. would take much longer to adopt in other jurisdictions, because most countries do not have pre-existing, publicly available spectrum license databases comparable to the Commission's ULS database. In the meantime, under the checkerboard approach for LPI access proposed in the NPRM, equipment manufacturers seeking to market LPI devices globally would either have to (1) produce devices on a per-country or per-region basis, increasing the cost of producing, shipping, and stocking increased types of units, or (2) produce a single device that includes flexible, region-specific functionality, causing a device to use only part of its capability at any time even while incurring higher component costs for wider tuning front-ends. Both options would stifle deployment—increased costs required to enable different sub-bands depending on the region will deter equipment manufacturers from investing in LPI devices for 6 GHz. Finally, inconsistent band plans between the U.S. and other countries could impair the user experience of client device owners when traveling between regions due to increased scanning delays required for non-GPS enabled devices such as laptops and tablets to listen in vain for APs on disallowed channels.

B. Low-Power Indoor Operations are Safe and Will not Cause Harmful Interference to Licensed Services in the 6 GHz Band.

The Commission can safely authorize LPI operations across all four 6 GHz sub-bands without creating a risk of harmful interference to incumbent licensed operations. As explained in the

RLAN Group Comments, LPI operations can coexist with all types of licensed services in the 6 GHz band.[29] In fact, a low-power indoor WLAN access point would have to win the "interference lottery" by somehow falling into four different and unlikely corner-case situations simultaneously—related to space, energy, frequency, and time—in order to cause harmful interference to an FS link.

First, an LPI device would have to fall into the spatial corner case. Here an AP would have to be situated near enough to the main beam of an FS link to be able to cause interference. The chances of this occurring are extremely low because low-power *indoor* devices are required to be *inside* buildings, and FS links operate outdoors, pointed away from buildings and other obstructions.[30] Thus, the only way for an LPI device to fall into this corner case is to be in a building that is within the 3-dB main beam of an FS receiver. As explained in the RLAN Group Comments, while this is possible, the geometries of FS design compared to the locations of LPI access points make this very rare.[31] FS links are generally designed to avoid tall buildings, and even then, the AP would have to be on just the right floor and on the same side facing the FS receiver.[32] While it is true that tall buildings have been erected into the main beam of FS paths after the fact, those buildings will attenuate more of the RLAN signal due to the concrete and steel construction needed to reach tall heights and the energy efficiency requirements of modern building codes.[33]

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29 *See* RLAN Group Comments at 18-30.

30 *See* Appendix 2: Declaration of Ira Wiesenfeld Regarding Low-Power Indoor Radio Local Area Network Devices Interfering with Fixed Station Microwave Services at 7-9("Declaration of I. Wiesenfeld").

31 *See* RLAN Group Comments at 20-22.

32 *See* Declaration of I. Wiesenfeld at 2.

33 *See* RLAN Group Comments at 23-24; *see also* RLAN Group Comments, Appendix E: Building and Vehicle Attenuation at E-4 ("BEL Appendix").

Second, the unlucky LPI device would also have to simultaneously satisfy the energy corner case. Here the LPI device would have to emit energy strong enough to cause harmful interference to an FS receiver (in addition to meeting the spatial corner case). But LPI access points will operate at *lower* power levels than standard-power APs, at only 250-milliwatt (24-dBm) conducted power limits. Additionally, the indoor location of the LPI access points will cause signal attenuation in addition to existing propagation losses. Buildings provide a significant source of attenuation, dramatically reducing the already low signal strength emitted by an LPI device. Attenuation is at least 30 dB for buildings constructed using thermally efficient materials (as is increasingly required for all new and remodeled buildings) and 18 dB for any buildings not constructed with thermally efficient materials.[34]

Third, even if the unlucky LPI access point is situated where it could interact with an FS link and is emitting enough energy to cause interference at an FS receiver, it can only pose a risk if it also simultaneously falls into the frequency corner case. Here it must operate partially or entirely co-channel with the FS link in question. The dominant FS channelizations in the U.S. are 10 MHz and 30 MHz, which represent a mere 0.8% and 2.5% of the 1,200 MHz contemplated in this rulemaking, making it unlikely that an LPI AP and an FS link would happen to transmit on the same overlapping frequencies.

Fourth, having already satisfied the spatial, power, and frequency corner cases, the LPI device would have to simultaneously fall into the timing corner case. Since the original 802.11a standard was ratified twenty years ago, Wi-Fi devices have capped the maximum airtime of a single data frame transmission at just over 5 milliseconds; and the overwhelming majority of transmissions

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[34] *See* 6 GHz NPRM at ¶ 70; BEL Appendix at E-2.

are less than 0.5 milliseconds.[35] For continuous data streams such as high definition video, research has also shown that Wi-Fi devices consume on-air duty cycles of under 1%.[36] In addition, the record in this proceeding reflects that average fade margins are at least 30-40 dB *above the C/I level required to achieve the link performance objective*, and the RKF study found they could be significantly higher, with a median of 50 dB.[37] Therefore, falling into the time corner case would require a fade of substantial magnitude to occur at the exact time an RLAN device is transmitting. This means that an LPI device must be (1) in the window of a building that is in the main beam of an FS link, (2) transmitting without any attenuation and close enough to the FS receiver that received power is high enough, (3) transmitting on the same channel, and must also be (4) transmitting at the same time as a deep fade on the FS path. The possibility of these four interference conditions all aligning at the same time is unlikely at the outset and is made more unlikely still by the intermittent "burst" nature of WLAN transmissions.

Finally, even if an AP wins all four prerequisite "lotteries"—space, energy, frequency, and time—an FS link is still exceedingly unlikely to experience any real-world impact or decreased function due to a small, highly attenuated amount of WLAN energy. High-reliability FS links include features such as forward error correction, adaptive modulation, and path diversity to help avoid

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35 Chuck Lukaszewski & Liang Li, *Validated Reference Design Very High Density 802.11ac Networks Theory Guide,* Aruba Networks at 24 (Mar. 19, 2015), https://community.arubanetworks.com/t5/Validated-Reference-Design/Very-High-Density-802-11ac-Networks-Validated-Reference-Design/ta-p/230891.

36 *Presentation of Additional Measurements & Analysis Confirming the RLAN Duty Cycle*, Hewlett Packard Enterprise (Sept. 13, 2018), https://www.cept.org/ecc/groups/ecc/wg-se/se-45/client/meeting-documents/?flid=9010; *see also* RKF Engineering Solutions, *Coexistence Study for Radio Local Area Networks in the 6 GHz Band in the Continental United States* at 12, table 3-1 (Jan. 25, 2018) in Letter from Paul Margie to Marlene Dortch, GN Docket No. 17-183 (filed Jan. 26, 2018) ("RKF Study").

37 *See* RKF Study at 22.

outages. But the probability that WLAN signals from LPI APs would require FS links to fall back on such protections is vanishingly small.

Furthermore, the ratio of carrier to interference power (C/I) is a useful and appropriate standard by which to understand the *de minimis* potential for LPI operations to interfere with FS links. Although HPE supports interference to noise (I/N) protection criteria for AFC control of standard-power APs, a C/I analysis is instructive for understanding that LPI operations will not cause harmful interference to FS licensees. The C/I analysis of proposed operations in the 6 GHz band contained in the Declaration of Ira Wiesenfeld shows that LPI operation is safe for FS licensees, and that any power received at the FS receiver from an LPI AP in the main beam would be vanishingly small compared to the received power of the FS signal at the FS receiver, resulting in a C/I ratio of 49 dB or more in favor of the FS path in challenging scenarios.[38]

HPE therefore supports the analysis in the RLAN Group Comments regarding the safety of authorizing LPI operations to share with FS services and other licensed services in the 6 GHz band.[39] What's more, the Commission's own explanation of why LPI operations are safe in U-NII-6 and -8 also demonstrates that it is safe in U-NII-5 and -7.[40] U-NII-5 and -7 contain the same incumbent FS and FSS uplink services as U-NII-6 and -8.

The same analysis regarding the ability to conduct LPI operations without causing harmful interference to incumbent licensees applies to very-low-power ("VLP") operations at 14 dBm or less, both indoors and outdoors, across all four sub-bands. Devices operating at such low power levels, combined with building attenuation and propagation losses, present no measurable risk of

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38 *See* Declaration of I. Wiesenfeld at 8, 12-15.

39 *See* RLAN Group Comments at 18-30.

40 *See id.* at 18-19.

harmful interference, and would produce benefits for consumers. A VLP device class would complement the two device classes proposed in the NPRM through specialized, short-range connectivity applications. As explained in the RLAN Group Comments, the possibility of real-world interference to FS receivers from VLP devices is extremely small, and the Commission should approve the operation of such devices.[41]

C. Analysis of Real-World Fixed Service Links Shows that Incumbents Can Share the Band with Low-Power Indoor RLANs.

HPE recognizes the importance of the services provided by FS licensees in the 6 GHz band and understands that FS links must operate with high reliability. The Commission has noted that in proposing to allow unlicensed use in the band, it is committed to preserving and protecting "the important base of incumbent users in these frequency bands."[42] HPE shares this commitment and urges the Commission to authorize low-power indoor use across the 6 GHz band because it believes that such operations will protect licensed FS services and will not cause harmful interference.

However, some in the FS industry have focused their advocacy exclusively on the rare situations where interference would hypothetically be possible under a series of unlikely conditions in a manner that does not allow the FCC to understand the typical configurations of WLANs and FS links.[43] It would be unwise for the Commission to adopt rules for the entire band based on

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41 *See id.* at 36.

42 6 GHz NPRM at ¶ 2.

43 *See, e.g.*, Letter from Cheng-yi Liu and Mitchell Lazarus, Counsel for the Fixed Wireless Communications Coalition, to Marlene H. Dortch, Secretary, Federal Communication Commission, GN Docket No. 17-183, ET Docket No. 18-295, at 6 (filed Oct. 2, 2018) (contending that indoor RLANs "pose a serious interference threat"); Letter from Cheng-yi Liu and Mitchell Lazarus, Counsel for the Fixed Wireless Communications Coalition, to Marlene H. Dortch, Secretary, Federal Communication Commission, GN Docket No. 17-183, at 4 (filed Aug. 28, 2018) (arguing that indoor RLAN operation at "powers low enough to pose no material risk to the FS are also too low to be useful").

assumptions built on cherry-picked FS links that do not represent the bulk of real-world deployments, especially when those rules could unnecessarily undermine investment and innovation in the 6 GHz band. Consideration of real-world FS configurations demonstrates that the Commission can confidently allow low-power indoor operations throughout the 6 GHz band.

FS links are designed to be robust from the outset, making them especially resilient and unlikely to be affected by faint RLAN signals. The more critical an FS link, the more reliability measures its engineer is likely to include in its design, including higher-quality and higher-gain antennas, employing spatial or frequency diversity, and cross-polarization.[44] Short-haul links using automatic transmit power control to reduce power to improve spatial reuse or coordination nonetheless have extra available margin to temporarily increase the signal power further in the event of coincident extreme fading and transient noise floor rise. Further, significant advances in radio technologies across the board have benefitted FS networks. Compared to even 20 years ago, the depth and frequency of fades has been significantly reduced for a given path and distance. Forward error correction, improved receivers, improved low-noise amplifiers, and orthogonal frequency-division multiplexing have improved the strength and capabilities of FS systems while enabling ever higher performance.[45]

In addition to being technologically engineered for reliability, FS links are also physically constructed and located to minimize obstruction not only from buildings where RLANs may exist, but also from trees, hills, bridges, and other large obstacles. FS engineers often attempt to clear most

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[44] *See* Declaration of I. Wiesenfeld at 15-16.

[45] *See id.*

or all of the 3-dB beamwidth to a distance of several miles from each end of a link to mitigate against future construction occluding a Fresnel zone.[46]

In rare circumstances, a building or structure may be constructed after placement of an FS link. In this case, an FS licensee might re-engineer the link frequency or diversity strategy because of the building obstruction. However, even if this did not occur, such a recently constructed building must comply with modern energy efficiency building codes that require thermally efficient building materials, including "low-e" windows. This would greatly reduce or eliminate the emission of radio waves from within.[47] As the Commission recognized in its NPRM, the prevailing ITU model for building loss predicts losses of at least 30 dB for thermally efficient buildings,[48] thus effectively nullifying the possibility of harmful interference caused by a low-power indoor WLAN device inside of a building constructed in the path of an FS link after the link was constructed.

Considering the realities of how FS networks are engineered and constructed, the Commission should cautiously evaluate arguments from the FS industry based on unrealistic or very rare FS situations. Not only do FS links contain significant resiliency and technical reinforcement, but, as discussed in the previous section, RLAN signals will almost never reach an FS receiver at levels sufficient to cause harmful interference in the first place without an almost impossible combination of conditions occurring simultaneously. The Commission should therefore be confident that it can authorize LPI operations throughout the 6 GHz band without causing harmful interference to, much less actual disruption of, FS links.

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46 *See id.* at 7-9.

47 *See* BEL Appendix at E-3, E-4.

48 6 GHz NPRM at ¶ 70.

D. Equipment Manufacturers and Commission Rules Can Prevent the Outdoor Use of Low-Power Indoor Access Points.

The Commission also sought comment on rules to enforce indoor use of LPI devices.[49] HPE is confident that with the right FCC rules, we, along with other original equipment manufacturers, can prevent both accidental and intentional outdoor use of indoor-only devices.

As an initial matter, it is critical to understand the historical cost reasons why indoor equipment was used outdoors and the fundamental changes in the outdoor RLAN market that have eliminated the financial incentives to do so. In 2008, the list price of the top-of-the-line Aruba AP-70 indoor 802.11a/g access point was $595, compared with a list price of $1,795 for the Aruba AP-80M outdoor AP – a threefold price differential. Assuming the cost for external antennas, conduit and cable was the same for each, and the price of a weatherproof "NEMA enclosure" was $100, then a customer could save over $1,100 per AP by using indoor models and retrofitting them for outdoor use. Today – over 10 years later – the price differential between indoor and outdoor equipment has narrowed radically, and in some cases has even inverted. The list price of Aruba's 802.11ac Wave 2 fully hardened outdoor AP-365 is now just $1,360, which is *less than* our top-of-the-line indoor 802.11ac Wave 2 AP-345 at $1,460. In addition to price similarity, another recent development is the trend towards fully integrated antennas on outdoor products in a variety of antenna directionalities. This saves the customer both the cost of purchasing antennas as well as the labor and materials for cabling, mounting, and weatherproofing. These savings can be substantial. Continuing the example above, the AP-365 as shown in Figure 3 below requires nothing but an Ethernet cable to install for outdoor use. However, the indoor AP would require an external antenna for an additional $475 in addition to the NEMA enclosure and pigtails, making the outdoor AP

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[49] *See id.* at ¶ 71.

more than 1.5 times less expensive than the indoor AP for outdoor use. These structural changes in the Wi-Fi market will not be reversed, and ultimately cost drives consumer behavior.

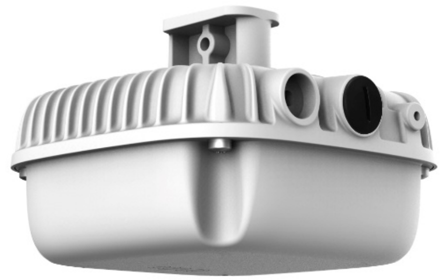

Figure 3: Aruba AP-365 802.11ac Wave 2 IP68 Outdoor Access Point with Integrated Antennas

Given these dynamics, the instances of outdoor use of indoor-only devices would be rare even without FCC rules to provide extra security. Nonetheless, if the Commission remains hesitant, HPE recommends that the Commission reduce the chance even further by prohibiting the use of connectorized antennas on LPI devices. Requiring LPI devices to use fully integrated antennas effectively forecloses any meaningful consideration of outdoor use. For those legitimate indoor use cases where an AP requires an external antenna, it can be met by using standard power APs under AFC control. The Commission could also adopt requirements for "indoor use only" labels to inform and remind customers that LPI devices are not authorized for outdoor use. Additionally, the Commission could adopt device certification requirements allowing LPI operation only when connected to mains power (including, for example, power-over-ethernet DC power), thus preventing outdoor operations in battery-powered mode.

However, the Commission should avoid imposing requirements that have the potential to significantly hinder LPI operations without providing any real interference-protection benefit, such as the proposal to require LPI devices to monitor GPS signals and cease transmissions if a GPS signal is detected.[50] Such a requirement would create substantial burdens for LPI users because of the potential for automatic shutoffs in the event of false positive signal reception and would unnecessarily drive the price of LPI devices up, possibly foreclosing their use in common deployment models.

III. A Straightforward But Robust Automated Frequency Coordination System Will Protect Licensees While Allowing Standard-Power Access Points to Operate in the Band.

HPE agrees with the Commission's proposal to allow standard-power RLANs to operate governed by an AFC system. The AFC framework will allow standard-power APs to operate and protect licensed users by using a database of licensee information to determine whether an unlicensed AP may safely operate. This automated process draws from the Part 101 frequency coordination process that is already successful in protecting licensed users in the band.[51]

HPE also agrees with the Commission's goal of creating a simple but strong AFC framework that is easy to implement and consistently achieves its sole goal: to allow standard-power unlicensed APs to operate *only* on frequencies and in locations where they will cause no harmful interference to licensed services. The Commission's AFC proposal draws from its considerable experience with other spectrum-sharing databases and wisely prioritizes simplicity, usability, and diversity of deployment scenarios to support intensive but non-interfering unlicensed use in the band.

The AFC protocol can be broken down into several component processes, which will be performed almost instantaneously. First, a standard-power AP will request permission to operate and will provide the AFC with its location, ideally along with a set of desired frequencies or

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50 *See id.* at ¶ 71.

51 *See* 47 C.F.R. § 101.103.

requested operating power. Next, the AFC will identify all FS receivers within a certain area on the same frequency and test the path to those receivers to determine the power level at which that receiver would hear the potentially interfering signal. In an alternative implementation, the AFC could pre-compute a series of protection contours for each FS receiver outside of which an RLAN device at a given power level would not cause harmful interference. The AFC will then inform the unlicensed device which frequencies are available in that location, possibly with maximum allowable EIRPs if lower than the standard operating power. The AFC would only allow an AP to operate on a frequency if it will not cause the I/N ratio at the licensed receiver to exceed the applicable interference protection threshold, as determined by the applicable propagation model, receiver location and antenna type, and AP location.

As described in the RLAN Group Comments, while the core protections will remain the same in every AFC, the FCC should permit innovation so that protocols and configurations will look different from one AFC operator to another and from one AP to another. For example, one approach would be an integrated model, which would involve a standard-power AP with AFC functionality built into the AP itself.[52] Alternatively, the AFC could be a stand-alone cloud-based system operated either by an AP manufacturer or by a third-party operator, and APs could access the AFC through a proprietary arrangement or an open standard.[53] However, the common denominator is that no AFC will allow a standard-power AP to increase interfering signals at a licensee's receiver past the acceptable interference protection threshold.

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52 RLAN Group Comments at 60-61.

53 *Id.* at 61-62.

A. The Commission Should Allow Flexibility in AFC Design and Configuration to Support Innovation and to Serve Diverse Consumer and Enterprise Needs.

There is no one-size-fits-all Wi-Fi AP. As discussed above, equipment makers currently produce myriad different APs and devices to meet diverse customer needs, with different configurations, capabilities, and price points. The same will be true of standard-power operations in 6 GHz. The Commission should encourage this innovation and allow OEMs to meet the need for specialized APs by adopting AFC rules that require reliable interference protection—but do not command that every company use a specific technology or approach to achieve this protection.

For location, AFC systems could use several different methods for calculating the dimensions of protection contours, including z-axis calculations regarding the height of licensed receivers relative to RLAN APs. The rules should allow AFCs to account for height information and, where necessary, account for height uncertainty, just as it would for uncertainty along the x- and y-axes. Increased location accuracy along any axis will result in more usable spectrum for the unlicensed AP, but it would not increase the risk of interference to the licensed receiver because the AFC will produce larger protection contours to account for location uncertainty. Thus, allowing APs to use different technology will allow manufacturers to prioritize and invest in location granularity in situations where access is more valuable along a certain axis without reducing interference protection.

For example, an AP designed for outdoor restaurants, shopping areas, or public spaces in urban or suburban locations could benefit tremendously from location-specificity along the z-axis. Those APs could take advantage of the height of most FS installations (70 feet above ground level on average[54]) compared to their desired deployment scenarios at ground level because spectrum

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[54] Declaration of I. Wiesenfeld at 18.

availability should be inversely proportional to height. Investing in height-specific sensing and calculation abilities would therefore be more valuable for that class of APs, and some manufacturers will have a strong incentive to invest in a more capable device to meet their customers' needs.

The Commission should similarly permit a range of interface and communication protocols between the AFC system and AFC-controlled device, depending on individual network management needs. The interface could be based on a public standard, or could be proprietary. Unlike in other bands where interference-control mechanisms like the spectrum access system ("SAS") must ensure that SAS networks talk to each other, each 6 GHz AFC system will work independently. The AFC must prevent each device under its control from operating within the zone where it could cause harmful interference to a licensed receiver on a certain frequency. But it does not need to know where devices under the control of another AFC are operating. Furthermore, proprietary AFC protocols customized for communication with a set of APs could decrease the time necessary to grant permission to operate and provide benefits for specialized AP operators. The Commission therefore should authorize AFCs to operate using whatever protocol achieves the interference protection goal.[55]

B. The Commission Should Permit Portable and In-Vehicle AFC-controlled RLANs.

Portable APs in vehicles such as trains, planes, buses, and cars are major use cases for unlicensed technologies today and are likely to increase in the future. Portable RLAN deployments are also a crucial tool for military and commercial operations that change locations periodically and are deployed for mobile command points, mining operations, and energy, precision agriculture and

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[55] As explained in the group comments, device certification would involve verification that the AFC identifies the correct available frequencies at a set of FCC selected test points and device operating parameters. *See* RLAN Group Comments at 62-63.

research applications. The NPRM sought comment on whether the Commission should permit these types of operations in the 6 GHz band.[56] HPE recommends that it should.

The AFC framework will allow portable standard-power APs to operate without risking harmful interference to licensed services by requiring devices to re-authorize operation through the AFC when in motion. For a mobile standard-power AP inside of a vehicle, for example, the re-check interval would decrease proportionally to the increase in the vehicle's speed. Alternatively, the AFC could increase the size of the protection contour as the vehicle's speed increases in lieu of decreasing the recheck interval. The Commission's time-tested equipment certification system will ensure compliance. Provided that the manufacturer can demonstrate compliance with re-check and protection contour requirements at appropriate speeds, the Commission should certify the mobile AP.

Another common enterprise scenario involves mobile RLAN devices within a large privately or publicly owned facility that occupies several square kilometers but is nevertheless private property with controlled access. Examples include military bases, railyards and container terminals, oil fields, refineries, manufacturing plants, airfields, mines, quarries, power plants, and other industrial facilities. In this case, a simple geofence that fully encloses the property is all that is required. This would allow an AFC to provide available channels for the entire facility and RLAN devices in motion within the facility need never approach a recheck boundary.

The Commission should also permit 6 GHz RLAN operation inside aircraft above a safe altitude. Because signal attenuation due to aircraft fuselage is even greater than attenuation caused by motor vehicles, operation inside aircraft does not present a risk of harmful interference to

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[56] 6 GHz NPRM at ¶¶ 84-85.

incumbent licensees.[57] However, HPE agrees with the Commission's suggestion in the NPRM to prohibit unlicensed APs from operating on unmanned aircraft systems. While manned aircraft have metal fuselages that cause substantial signal attenuation, unmanned aircraft generally do not include such structures to contain a wireless device and its signals.

C. The AFC Can Prevent Interference to Licensees Based on Appropriate Interference Protection Criteria and Accurate Licensee Information.

HPE notes with interest the Commission's suggested interference protection criteria ("IPC") of 0 dB I/N for AFC-calculated protection contours.[58] This value deserves further technical analysis and debate. The RKF Report considered exceedance rates for FS receivers at both -6 dB and 0 dB I/N. HPE and the RLAN Group have previously endorsed -6 dB in the record primarily on the basis of TIA Telecommunications Systems Bulletin ("TSB") 10-F.[59] The FS community accepted this value with no debate. However, adjustments to IPC proportional to increases in FS link fade margins; long-term vs. short-term protection criteria; and IPC calculation based on daytime vs. nighttime fading are all issues that warrant further discussion based on TSB 10-F.[60] Considering the exceptional robustness of FS systems, it is appropriate for the Commission to consider whether a 0 dB I/N IPC standard best serves the public interest by achieving the necessary level of protection while also improving the utility of the bands in question for unlicensed operations. While it is clear that a conservative -6 dB I/N IPC would protect incumbents, FS interests have not prepared studies

57 *See* BEL Appendix at E-6.

58 *See* 6 GHz NPRM at ¶ 43 (requesting input on appropriate interference protection criteria).

59 *See* Telecommunications Industry Association, *Interference Criteria for Microwave Systems*, Telecommunications Systems Bulletin 10-F (Jun. 1994) ("TIA TSB 10-F").

60 *See* TIA TSB 10-F at Sec. 4.2.3 (discussing fade margin factors); Alakananda Paul et. al., *Interference Protection Criteria*, National Telecommunications and Information Administration at 4-2, 4-8 (discussing the relationship between IPC and fade margins).

supporting such an aggressive IPC, and it is worth considering whether a sensitivity test would show that a 0 dB I/N could produce a better result overall for the country.

Returning to AFC operation, the AFC would calculate whether a standard-power AP will cause the I/N ratio at each fixed link receiver to exceed the appropriate IPC, and, if so, prevent APs from operating co-channel with the FS receiver at that location and channel. To accomplish this, as explained in the RLAN Group Comments, the most appropriate model for the 6 GHz band is the WINNER II model in urban and suburban areas for distances up to one kilometer and the Irregular Terrain Model ("ITM") combined with location-specific terrain data in rural areas for all distances and in urban and suburban areas for distances over one kilometer.[61]

To effectively prevent interference, the AFC will use the FCC's database that reflects the location, antenna characteristics, and other parameters of licensees' receivers. To encourage database accuracy, and as explained in the RLAN Group Comments, the Commission should allow licensees to update their existing ULS registrations to reflect real-world operating conditions, including receiver locations, channels, and other coordination information, without penalty. This amnesty window should apply so long as licensees certify that the change is a correction to information in the database rather than an operational modification to the licensed facilities. To facilitate this, the Commission should waive the Part 101 mandatory re-coordination process triggered under the rules when a licensee updates its location.[62]

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[61] RLAN Group Comments at 44; Declaration of Dr. Vinko Erceg at ¶ 19. The propagation model should also use a distance of 30 meters as an exclusion zone around all licensees' receivers. *See id.*

[62] *See* 47 C.F.R. § 101.103(d)(1) (requiring coordination prior to "filing an application for regular authorization, or a major amendment to a pending application, or any major modification to a license").

IV. THE COMMISSION SHOULD ADOPT TECHNICAL RULES TO ENABLE FUNCTIONALITIES IMPORTANT TO ENTERPRISE NETWORKS.

As one of the leading providers of managed WLAN infrastructure, HPE urges the Commission to adopt technical rules for 6 GHz that can support investment in and the success of enterprise networks.

A. Antenna Gain Rules Similar to Those in the U-NII-3 Band Will Allow Directional Antenna Systems to Function Efficiently and Without Causing Harmful Interference.

Unlicensed systems using directional antennas are central to enterprise customers, special events and venues, and managed use cases. To allow for these important use cases, the Commission should adopt rules that account for directional antenna systems and antennas with directional gain, and do so in a way that is consistent with the highly successful U-NII-3 band, rather than requiring that conducted power be reduced to offset antenna gain in excess of 6 dBi.[63] U-NII-3 rules permit the use of higher gain antennas with the limitation that, for non-point-to-point ("P2P") operations, conducted power must be reduced by 1 dB to compensate for antenna gain in excess of 6 dBi. For P2P operation, U-NII-3 rules do not limit the gain of transmitting antennas and do not require such a reduction in conducted power to compensate for high gain.

However, the NPRM's treatment of this issue for 6 GHz RLAN devices is ambiguous. On the one hand, it says that "[i]f a transmitting antenna with directional gain greater than 6 dBi is used, the maximum power and power spectral density shall be reduced by the amount in dBi that the directional gain is greater than 6 dBi."[64] But on the other hand, it cautions that "we are proposing no provisions for high gain antennas for unlicensed devices."[65] We take the former, more specific

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[63] 6 GHz NPRM at ¶¶ 78, 81.

[64] *Id.* at ¶ 78.

[65] *Id.* at ¶ 79.

statement to control, meaning that the Commission intended to propose rules similar to the existing U-NII-3 rules for non-P2P devices. Indeed, the ability to use higher gain antennas under such an approach is critical. Prohibiting antenna gain in excess of 6 dBi would be unnecessary and would greatly reduce the value of the band for key enterprise and WISP use cases. In addition, we urge the Commission to adopt a version of the U-NII-3 P2P rule to allow highly directional, steerable P2P beam systems that provide non-simultaneous point-to-multipoint operation.

B. The Commission Should Permit AFC-Controlled Client Devices to Send Brief Control Signals to APs for Network Attachment.

Experience in U-NII-2 and other 5 GHz bands encumbered by dynamic frequency selection ("DFS") requirements has demonstrated the importance of allowing client devices to send brief control signals to associate with access points. In DFS bands, client devices are not permitted to transmit until they receive an enabling signal from a DFS master device. This requirement, in addition to other challenges in complying with DFS rules, often results in periodic loss of connectivity for client devices during roaming, causing noticeable interruptions in real-time latency-sensitive applications. In turn, this behavior has been one factor impeding the adoption expected by both industry and the Commission. Based on this experience, and to speed adoption of 6 GHz devices, the Commission should allow RLAN client devices to transmit extremely brief—a few hundred microseconds in length—control signals to ensure that client devices can join or rejoin networks rapidly, preventing service disruptions that undermine user experience.

The Commission can enable such signals without risking harmful interference. Client control signals—which are extremely brief and occur infrequently—pose even less interference risk than LPI or standard-power RLAN operations. The attached study evaluates the potential incremental duty cycle in two typical RLAN deployment situations.[66] One is a residential apartment building comprised of 100 units on 5 floors, where most client devices are already associated with their home APs and therefore rarely need to send probing control signals. The second is an outdoor city block with 200 people, of whom 90% have unassociated devices that scan periodically because they are away from home networks. Using publicly available measurements of scanning frequency, the incremental duty cycle of such control signals is just 0.0001% for the residential building case and 0.001% for the outdoor city block case, confirming that these signals raise no significant interference concerns.[67]

V. CONCLUSION

HPE commends the Commission on its careful and innovative approach to opening the 6 GHz band to unlicensed operations. The framework announced in the NPRM will allow for more efficient use of the band while protecting licensees from harmful interference, and the AFC-authorization framework for standard-power devices refines the Commission's experience with database-authorized spectrum sharing in other bands. HPE urges the Commission to adopt the framework proposed in the NRPM, with a set of key modifications to ensure the band becomes a success: (1) permitting low-power indoor and very-low-power unlicensed operations across the entire 6 GHz band; (2) adopting simple rules that allow flexibility in AFC design but mandate robust interference protection; (3) allowing portable, standard-power APs to operate under AFC control; and (4) approving technical rules to enable directional antenna systems and reliable client device connection.

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[66] *See* Appendix 1: Duty Cycle Analysis of Wi-Fi Client Network Discovery Probe Requests in Two Primary Deployment Scenarios ("Duty Cycle Analysis of Probe Requests").

[67] Duty Cycle Analysis of Probe Requests at 3-5.

Respectfully submitted,

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February 15, 2019

Appendix 1

Before the
FEDERAL COMMUNICATIONS COMMISSION
Washington, D.C. 20554

In the Matter of	)	
Unlicensed Use of the 6 GHz Band	)	ET Docket No. 18-295
Expanding Flexible Use in Mid-Band Spectrum between 3.7 and 24 GHz	)	GN Docket No. 17-183

APPENDIX 1 TO COMMENTS OF HEWLETT PACKARD ENTERPRISE COMPANY:

DUTY CYCLE ANALYSIS OF WI-FI CLIENT NETWORK DISCOVERY PROBE REQUESTS IN TWO PRIMARY DEPLOYMENT SCENARIOS

1. INTRODUCTION

The 802.11 protocol defines an active probing mechanism by which client devices transmit a control signal called a "probe request," which solicits a response from access points (APs) on the channel, rather than passively scanning for AP beacons. Client devices use this to accelerate the connection process, especially during roaming. Without the ability to conduct a limited number of active probes, Wi-Fi clients may experience roaming delays for latency-sensitive applications such as Wi-Fi Calling. This is because passive scanning can take up to 100 milliseconds per channel – which is the duration between successive "beacons" that announce the presence of a Wi-Fi network – to identify the existence of an AP. Wi-Fi clients generally scan each channel in sequence, so that a complete scan of the 25 authorized 5 GHz channels in the U.S. could require as much as 2.5 seconds.

Active probing solves this problem by enabling a range of channels to be scanned for APs within just a few milliseconds per channel. This process leads to very brief transmissions by the client devices even when not associated with an AP.

Mobile device manufacturers use active probing as little as possible because it consumes energy from the battery. Implementations vary, but each device follows proprietary rules to decide when to probe, in what sequence, and how to select a candidate AP for a connection request.

2. SCENARIO DESCRIPTIONS

Two common deployment scenarios are considered in this analysis:

1. An urban outdoor city block with 200 people, each of whom has on average 1.5 Wi-Fi enabled mobile devices. (For instance, each person has a smartphone, but only half the people have a tablet in a backpack or purse.) In this case, it is assumed that 90% of the devices are unassociated because they are "away" from their home networks. As a result, they will probe more frequently.
2. A residential multi-dwelling unit with 100 apartments, in which there are 2.58 people per apartment, each of whom has 10 individual Wi-Fi enabled devices. It is assumed that only 1% of the devices are unassociated – since they should almost all be in range of their home networks.

3. PROBE REQUEST INTERVAL & DURATION

Active probing behavior has been the subject of several public research papers. This data is used to estimate the airtime consumption of a typical Wi-Fi device. Two values are required to produce a duty cycle for active probe transmissions:

- The average time interval between initiating an active probe sequence, and
- The average airtime duration of a probe request transmission.

For purposes of this analysis, only probe requests are modeled. This is because in the 6 GHz band, a probe response would constitute an "enabling signal" that positively indicates that a particular channel is usable by an authorized device class. This could be a low-power indoor (LPI) access point, or an AFC-managed standard-power access point. Either way, the energy associated with transmissions from an authorized unlicensed AP under AFC control or operating at low power, indoors, would not cause harmful interference to incumbents.

a. Probe Request Interval

For unassociated devices, the interval between probe requests depends on client device manufacturer, operating system, number of known networks, etc. In [1], probe request behavior was measured for four different clients. For two of the clients, the majority of the intervals were between 40 and 60 seconds. For the other two clients, the intervals were spread between 0 to 80 seconds.

In [2], they found that the Android 4.4.2 system broadcasts about one burst every 72 seconds, and the iOS 8.1.3 system broadcasts about one burst every 330 seconds.

In [3], they found that most of the average intervals lie between 20 seconds and 45 seconds.

In [2], they also measured the beacon interval for associated devices. Android 4.4.2 and iOS 8.1.3 systems largely stop broadcasting probe requests once connected.

b. Probe Request Duration

In [1], probe request frames were measured to be between 143 and 216 microseconds.

4. SCENARIO #1 - ANALYSIS FOR URBAN OUTDOOR CITY BLOCK

Consider a 100 meter stretch of street, with 100 people walking on either side of the street as shown in Figure 1. Between smartphones and other portable Wi-Fi enabled devices (e.g. tablet, watch) each person has on average 1.5 devices on their person. We assume that 90% of the devices are unassociated, whereas 10% will be associated with an AP or mobile hotspot (e.g. in the case of a Wi-Fi enabled watch).

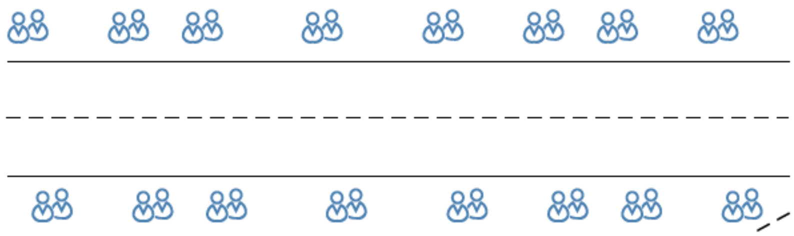

Figure 1 – Urban city block scenario

Each device may scan all of the 20 MHz channels, which will include:

- 2.4 GHz channels: 3
- 5 GHz channels: 24
- 6 GHz channels: 59

Using the parameters above, duty cycle of the client device probe requests is 0.001%. The computation is given below:

Parameter	value	equation
Number of People (P)	200	
Devices / person (D)	1.5	
% Unassociated Devices (UN)	90	
Total Number of Channels (Ch)	86	
Probe Request Interval, sec (PRI)	60	
Probe Request Duration (usec) PRD	200	
Total Number of devices (S1)	300	P*D
Total Number of devices per channel (S2)	3.4883721	S1/Ch
unassociated devices per channel (S3)	3.1395349	S2*UN/100
Total Probe Request duration per interval, usec (S4)	627.90698	S3*PRD
Duty Cycle (%)	0.0010465	S4/PRI

At this duty cycle, it would require 1,000 such city blocks with a total of 100,000 people outdoors to generate a 1% duty cycle. Such an area would be far larger than any FS incumbent receiver beamwidth, and in any case, would be at ground level deep in the clutter field under non-line-of-sight conditions. Active probe control signals sent by client devices for network attachment purposes thus pose no meaningful risk of harmful interference to incumbent operations.

5. SCENARIO #2 - ANALYSIS FOR RESIDENTIAL ENVIRONMENT

Consider a residential building. To determine the average number of units in a residential building, we consider data from [5] as given in the table below.

# of Units on Property	All	1 unit	2 to 4 units	5 to 24 units	25 to 49 units	50 to 99 units	100 to 149 units	150 units or more
# of buildings	22,519,000	19,283,000	2,551,000	478000	116000	47000	16000	27000
# of units	47,543,000	19,283,000	6,523,000	4,938,000	4,081,000	3,249,000	1,908,000	7,561,000

If we exclude properties with less than 25 units, and only consider larger buildings, 21% of buildings have 100 or more units, covering 56% of the total units. Therefore, we will use 100 units as a representative size of a residential building. This can be visualized in Figure 2 as a five-story building with 20 apartments per floor.

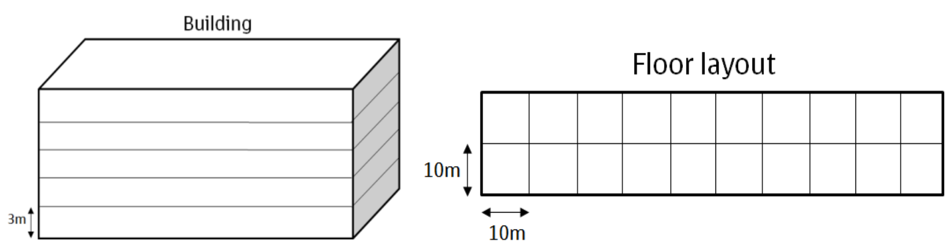

Figure 2 – Residential multi-dwelling unit scenario

[4] states that the average number of people per household is 2.58. And we will assume that number of devices per person in a household is 10 as used in the RKF Study.

Unlike in the street environment, where most devices are unassociated with any AP, in a residential environment most devices will remain connected to an AP after initial installation. Therefore, there is only a very small percentage of devices (1%) that are unassociated in a residential environment.

Following the same analysis used above for the street environment, **the duty cycle of the client device probe requests is two orders of magnitude less, at just 0.0001%.** The following table gives the calculation for a residential scenario:

Parameter	value	equation
Number of dwellings (DW)	100	
Number of People (P) per dwelling	2.58	
Devices / person (D)	10	
% Unassociated Devices (UN)	1	
Total Number of Channels (Ch)	86	
Probe Request Interval, sec (PRI)	60	
Probe Request Duration (usec) PRD	200	
Total Number of devices (S1)	2580	DW*P*D
Total Number of devices per channel (S2)	30	S1/Ch
unassociated devices per channel (S3)	0.3	S2*UN/100
Total Probe Request duration per interval, usec (S4)	60	S3*PRD
Duty Cycle (%)	0.0001	S4/PRI

At this duty cycle, it would require 10,000 such buildings, containing a total of nearly 2.6 million people with a collective total of 26 million devices, to achieve a 1% duty cycle. That number of buildings is far greater than what could be encompassed in the beamwidth of any incumbent FS receiver. The fact that Wi-Fi devices are "home" and therefore rarely need to do any active probing is a critical factor in this outcome. Again, this analysis demonstrates that the use of active control signals by client devices for network association poses no material risk to incumbents.

6. REFERENCES

[1] Detlef Fuehrer, *Study on the radio emissions of idle IEEE 802.11 WLAN devices*, JRC Science and Policy Report (2014).

[2] Julien Freudiger, *How Talkative is your Mobile Device? An Experimental Study of Wi-Fi Probe Requests*, Palo Alto Research Center, Proceedings of the 8th ACM Conference on Security & Privacy in Wireless and Mobile Networks (2015), https://frdgr.ch/wp-content/uploads/2015/06/Freudiger15.pdf.

[3] XiangFa Guo et. al., *Poster Abstract: Long-Term Observation With Passive Wi-Fi Scanning*, IEEE 24th International Conference on Network Protocols (2016).

[4] Dafne Lofquist et. al., *2010 Census Briefs: Households and Families: 2010*, United States Census Bureau, 1 (Apr. 2012), https://www.census.gov/prod/cen2010/briefs/c2010br-14.pdf.

[5] *Rental Housing Finance Survey*, United States Census Bureau (2015), https://www.census.gov/programs-surveys/rhfs/data.html.

Appendix 2

Before the
FEDERAL COMMUNICATIONS COMMISSION
Washington, D.C. 20554

In the Matter of	
Unlicensed Use of the 6 GHz Band	ET Docket No. 18-295
Expanding Flexible Use in Mid-Band Spectrum Between 3.7 and 24 GHz	GN Docket No. 17-183

APPENDIX 2 TO COMMENTS OF HEWLETT PACKARD ENTERPRISE COMPANY:

DECLARATION OF IRA WIESENFELD REGARDING LOW-POWER INDOOR RADIO LOCAL AREA NETWORK DEVICES INTERFERING WITH FIXED STATION MICROWAVE SERVICES

1. QUALIFICATIONS

My name is Ira M. Wiesenfeld, P.E. I am a licensed professional engineer in the state of Texas. My current occupation is a consulting radio engineer in the field of engineering, installation, maintenance and training of others in the field of radio communications. My formal training includes a BS in electrical engineering (1972), with post graduate studies in communications theory and business administration at Southern Methodist University in Dallas, Texas.

My other credentials include an FCC General Radiotelephone Operators License (GROL), which was grandfathered from an FCC First Class Operators license obtained in 1968. I wrote a substantial portion of the FCC GROL test for the FCC in 2002, which has been in use by the FCC since 2009. My other accomplishments include authoring 60 magazine articles on radio and communications, along with six books on communications and electronics.

I have worked as an independent consultant on radio communications systems since 1982. Before that time, I worked as a Field Technical Representative for Motorola Communications and Electronics (1972 to 1982), working on some of the largest communications systems in the US. Prior to working for Motorola, I worked as a communications technician for the City of Dallas from 1966 to 1972.

I have been involved with hunting and mitigating RF interference since 1966. One of the six books I have authored is Radio Frequency Interference from A to Z.

2. ABSTRACT

This document is a detailed report describing how low-power indoor 5.9250 GHz to 7.1250 GHz radio access points (RLANs) can share the 5.9250 GHz to 7.1250 GHz band with fixed microwave stations (FS) while causing negligible interference, based on my experience as a practicing FS engineer.

The exact paths of the licensed FS microwave can be ascertained from the FCC ULS database and any engineer working on a potential new FS path can use common open access mapping programs such as Bing or Google Earth to determine if there is a potential problem such as an occlusion of the Fresnel zone or 3-dB beamwidth by an existing building or terrain feature.

Since the FS stations are a licensed service with coordination as part of their application process, these existing and future stations expect and are entitled to a high degree of protection from any form of interference.

The RLAN units will be transmitting on the same bands and frequencies as the FS microwave stations, but the probability of their causing interference to the FS receivers is low because of multiple reasons. These are:

- FS engineers generally clear a significant fraction of the 3-dB antenna beamwidth of buildings and other potential obstructions to a distance of least 3 miles at the time FS paths are initially planned.
- As a result, there is a low probability that indoor RLANs are transmitting into the main beam of the FS receiver on an upper floor of a building, as the building itself would be an obstruction to the main beam.
- There would be a high loss of the signal between the interior of the building and the exterior going towards the FS receiving antenna, generally accepted as approximately 15 - 20 dB for a traditional building and 30 dB for modern, thermally efficient buildings.
- Any building erected after the FS path is deployed is very likely a thermally efficient building. All new buildings are now using high efficiency, low energy transfer materials. This will make any future RLANs inside of these buildings less of an interference source by a factor of 10 – 15 dB.

The physics and signal paths of fixed microwave systems will be discussed in detail. The particular items that allow the RLAN and the FS systems to be able to share the same spectrum with negligible interference will be explained in this document.

This report will primarily focus on buildings that are over six stories (e.g. above the clutter field) and where there is a known microwave FS path that is in the main beamwidth for that path. We will consider both non-energy efficient traditional buildings, as well as buildings that are energy efficient using low emissivity glass (“Low e” glass) and foil coated insulation in the walls. The choice of six stories for the lower limit of potential interference is based on the need for well-engineered microwave systems to keep the paths above the tree top level to prevent obstructions. In my experience, tall tree canopy can reach 75 feet, which is the effective height of a six-story building.

These taller buildings will generally only be found in the urban areas. In rural areas, where the long FS hops are found, the tall structures are industrial (such as a grain elevator) or municipal (such as a water tower).

In Section 5 of this document, I show calculations of the signal strength of the main power levels received by the 6 GHz FS systems using the formulas for free space loss and also the predicted power levels of the RLAN devices at various distances from the FS receivers. For microwave hops that are 20 miles or less, the RLAN signals are well below the FS main signal levels with a positive carrier-to-interference (C/I) ratio of between 35 and 55 dB.

3. TYPICAL DESIGN REQUIREMENTS OF MAJOR FS LICENSEES

There are four major groups of licenses in the 6 GHz band. These are:

A. Public Safety
B. Common Carrier
C. Railroads, Utilities, and Pipeline Companies
D. Broadcast

Each of these groups need and use these microwave services as an everyday part of their business or job function. The manner in which they use their microwave systems are critical and the use of the RLAN devices in the same band at the same time should not be a problem based on my experience for reasons explained herein.

A. Public Safety

Public safety agencies use 6 GHz to interconnect their various office data networks together on the same LAN. Another reason that public safety agencies use 6 GHz is to interconnect all of their radio sites together as a unified system which is required to be extremely reliable.

Public safety systems have specific engineered features to prevent disturbances in their network. Three such key attributes are common to all of the many public safety paths I have been involved with over the years. First, public safety FS links will be relatively short in distance between the sites. Many of the communications towers are closely spaced to provide 700/800 MHz two-way radio coverage in their jurisdictions and must generally be less than 10 miles between the sites. As a result, in most situations, the FS links are sufficiently short that deep fades on their system typical of long-haul links are never present. Second, because public safety microwave systems are required to be so reliable, the design engineer almost always uses redundancy and diversity as part of the design. And third, since public safety FS stations must always be up, the receive signal strength on these systems will always be comparatively high and not subject to fading or noise to the point where the carrier-to-interference (C/I) or carrier-to-noise (C/N) ratios of the signal pose a risk to the system.

This is borne out by an analysis of ULS records for Part 101 links in 6 GHz in Figure 1, which shows that 55% of public safety links are 16.5 miles (25 kilometers) or less, and fully 75% of such links are under 22 miles (35 km).

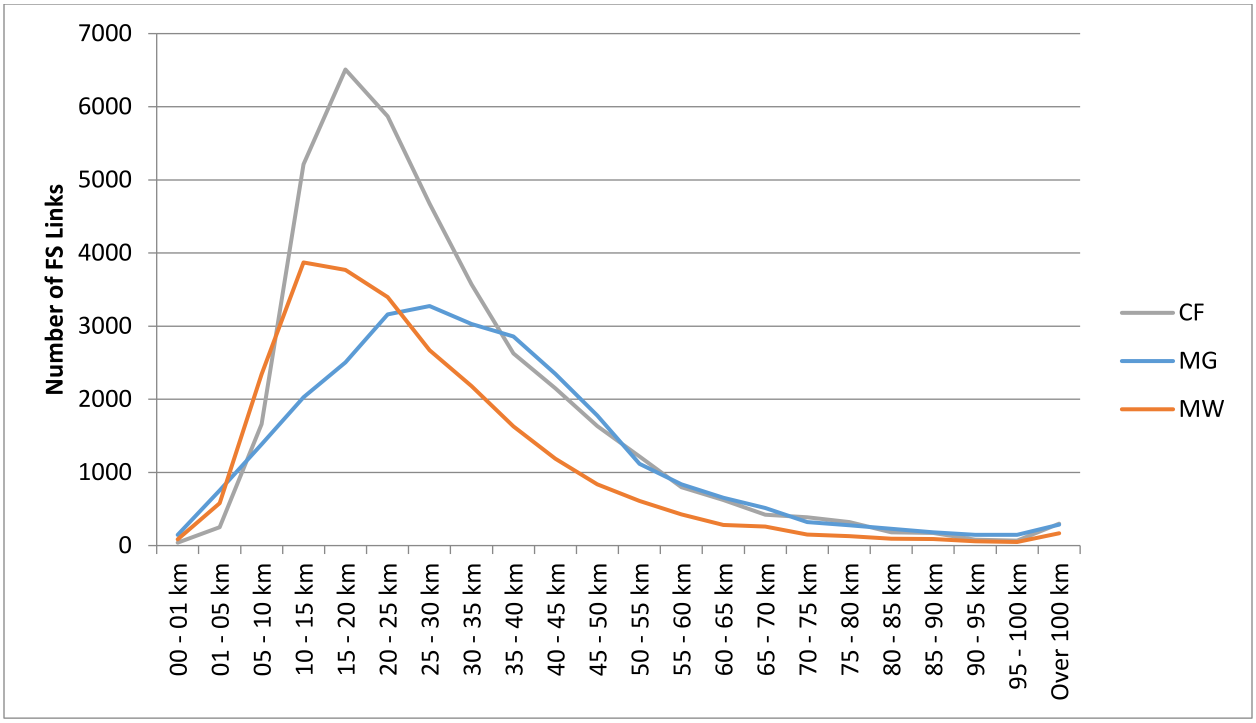

Figure 1 – FS Path Lengths Reported in ULS for Public Safety (MW), Common Carrier (CF) & Business Industrial (MG)

B. Common Carrier

The common carriers such as AT&T, Verizon, Sprint, Cox, US Cellular, T-Mobile, and others carry traffic for the entire country. Their clients expect good, reliable service, and they pay for good, reliable service. Because they do not know in advance what traffic will be on their networks at a given time, they also design reliability into their systems. In my experience, the carriers use newer technology systems, redundancy, and diversity to improve their reliability. The long hops between sites are normally in the rural parts of the country, while the urban areas have shorter distances between towers.

The standard for the carriers is to design their systems for 99.9999% reliability. In terms of how many minutes of outage per year this equates to, the number is 0.52560 minutes per year, or 31.5 seconds of outage per year.

As the carriers have grown in customer size, they have responded with newer technology to accommodate the increased traffic load on their systems. This newer technology is digital, with enhanced front ends, forward error correction, adaptive modulation, automatic transmit power control and other features. On any given path of any given distance, these newer radios inherently provide for fewer fades and stronger signals as compared with previous generations of equipment.

To my knowledge, the carriers have also moved a good part of their traffic from microwave systems that are limited in bandwidth to fiber optic systems that can carry much more bandwidth and no fades other than the backhoe fades that occasionally disturb these links.

C. Railroads, Utilities, and Pipeline Companies

Railroads, utilities, and pipeline companies have the majority of their FS stations in rural America. As such, in my experience the problem of taller buildings in an FS beam is not an issue with the majority of the FS microwave stations in this business sector. These FS stations are commonly stretched out in distance between the end points of their microwave spans. In addition, there are almost never habituated buildings along their Right-of-Way (ROW), and there are never tall buildings along their ROW.

ULS records in Figure 1 bear out my experience, which show that these MG service licensees have 20% fewer links than public safety links in the range of 16.5 miles (25 kilometers) or less, and the median length is 30 kilometers.

D. Broadcast

To my knowledge, most broadcast stations have their studios in urban areas and their transmitters in suburban, industrial or rural areas where their neighbors do not complain of the really tall towers. The urban areas usually have tall buildings, but the design engineers for FS microwave systems normally see a tall building in their path as an obstruction and always provide themselves a path with no obstructions.

4. PHYSICS AND FIXED SERVICE MICROWAVE RADIO FUNDAMENTALS

In the late 1890's, physicists demonstrated that centimeter wavelength radio waves could be generated and received, but it was not until 1931 that the first practical microwave radio was constructed to be able to send communication information. Since then, the technology has evolved such that television, carrier class communications, utility company SCADA, and public safety communications use microwave for communications of all sorts on a regular basis. Today, there are almost 100,000 licensed microwave systems in the US.[1]

a. Link Budget Engineering & Fade Margins

Long distance outdoor point-to-point links must be line-of-sight for signals in the UHF bands and above, and the amplitude of the signals follow the formulas that have been calculated and measured empirically over many decades such that engineers can predict the signal levels and any interference level. The typical received signal strength engineering objective that I employ in the design of a fixed service (FS) microwave system in the 6 GHz band would be -35 dBm to -20 dBm, depending upon the desired signal modulation and path reliability goal.

Almost all microwave signals are vulnerable to path signal fades, and these can be measured, predicted, and the effects mitigated with good engineering practices derived from experience. Such fades are more pronounced on longer links. Because these path signal fades do occur, all microwave systems are engineered with fade margins, which is a way of stating that the signal can be degraded

[1] See RKF Engineering Solutions, Coexistence Study for Radio Local Area Networks in the 6 GHz Band in the Continental United States at 44 (Jan. 25, 2018) in Letter from Paul Margie to Marlene Dortch, GN Docket No. 17-183 (filed Jan. 26, 2018) ("RKF Study").

by a certain amount in amplitude and the path still meets its minimum engineering performance requirement(s).

With good engineering practices, my experience is that the fades can be reduced to zero. As we will discuss in later paragraphs in this document, these systems can be engineered with redundant frequencies, paths, and polarization so that the effects of the fades can be reduced or eliminated. Sometimes, the path is too long, and the fade does cause an outage. In some of these cases, a shorter intermediate path can potentially be added to the excessively long paths so that the fades will not cause outages. In almost every case of RF interference between an FS receiver path and an RLAN system causing measurable interference, it will only be during a severe signal path fade on systems not well engineered with redundancy and/or that have path obstructions in their 3-dB beamwidth or Fresnel zones.

This document will detail how the FS microwave stations can co-exist with the proposed RLAN stations and that in practice, FS microwave paths will not be interfered with in a way that impacts link performance requirements.

b. Antenna Selection & Signal Suppression Outside the Main Lobe

All microwave radio systems use directional antennas with a very high amount of signal gain. The method of how an antenna provides signal gain is that radiation is reduced in non-useful directions and redirected into more useful directions. The higher the gain, the narrower the beam of the desired signal in the one direction. A typical 6 GHz antenna will have 38 dBi of gain, which will translate into a 3-dB beamwidth of 1.8 degrees. An analysis of ULS records provided in Figure 2 for the 5925 – 7125 MHz range shows that this is the most popular beamwidth. However, over 50% of all FS links use even narrower beams.

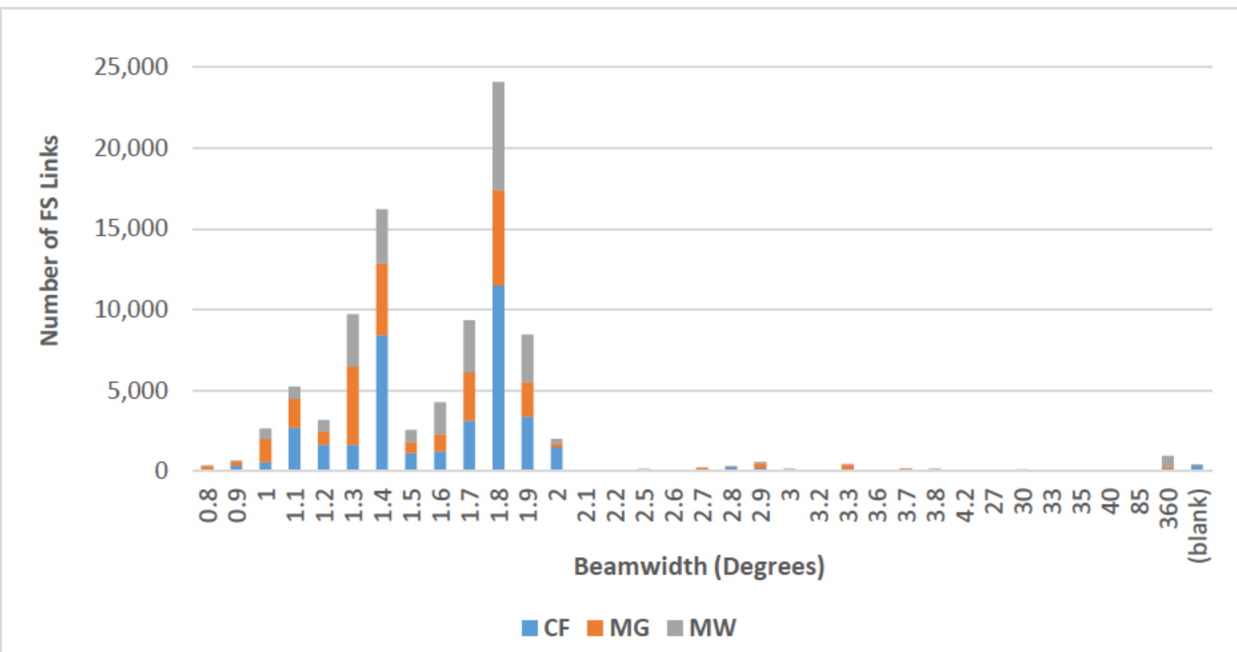

Figure 2 – FS Antenna Beamwidths Reported in ULS for Public Safety (MW), Common Carrier (CF) & Business Industrial (MG)

An interfering signal from a source outside of the main lobe beamwidth can be down by 20 dB to 90 dB in amplitude, depending upon the exact angle off boresight for a given antenna size and performance level.

c. Path Clearance Engineering

When designing a new microwave path, the path should be clear of any current obstruction or future obstruction. As part of the design of a new microwave system, the engineer will use tools such as free space path loss calculators, link budget calculators, Fresnel zone (FZ) calculators, and curvature of the earth calculators. Another tool will be the ULS listings or other services that compare new microwave paths to the existing licenses to ensure that there is no interference to the microwave radio path.

A second pass on the design will usually include a straight-line drawing using Google Earth to ensure that there are no obstructions in either the main beam path and no obstruction in the Fresnel zone clearance area for the direct line-of-sight path on paper or in front of a computer screen.

The next step for a good design is to print out a map using Google Earth and actually travel the path to visually ensure that there are no obstructions to the path, including trees, buildings, towers, windmills, power lines, or anything else that can affect the path. Another thing to look for is sites being excavated for buildings that could be a problem in the future. Trees that are in the direct path or the Fresnel zone can grow taller and wider, and these can be a source of problems in the future.

All microwave systems should be proposed and the engineering performed using good engineering practices, as it is very expensive and time consuming to make an error on the first try and have to redesign the path at a different site.

Because of Fresnel clearance zones and earth curvature, the longer the path, the higher that the microwave dish or panel antennas needs to be as compared to flat earth paths. On paths that start and end on high hills or mountains, this is normally not a problem.

One of the primary causes of sustained deep fades and signal degradation is when there is a physical obstruction close to the main, line-of-sight, and path. The microwave signal can bounce off of an obstruction and be 180 degrees out of phase with the main path, and this will result in a significant reduction of the actual signal level at the receiver site of the microwave path. If the area where this obstruction is located is within the Fresnel zone, there will be a reflected signal combining with the main line-of-sight path that is out of phase and the path is reduced by 20 to 30 dB at the receiver point.

This obstruction can be the ground, a tree, a building, a power line, or anything that can reflect a microwave signal. For this reason, as shown in Figure 3 I typically ensure that the Fresnel zone is completely above the clutter field which I define as approximately the height of a six-story building, or 60 to 70 feet.

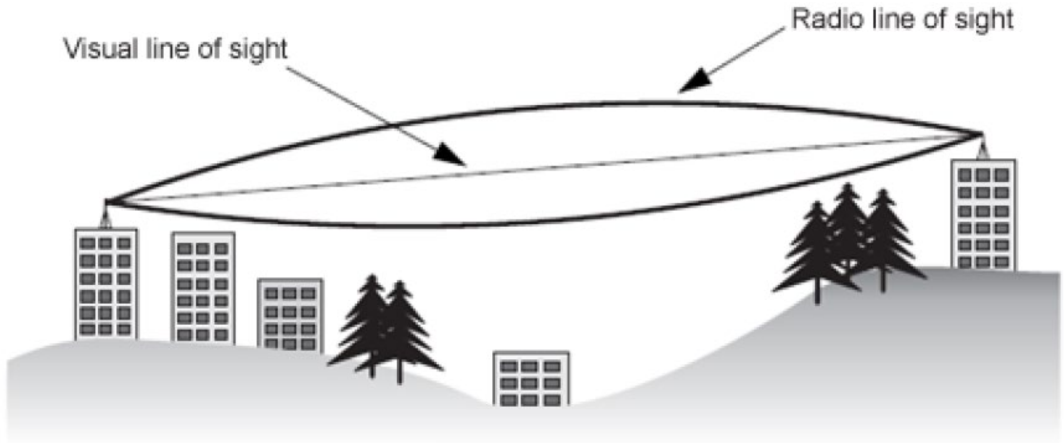

Figure 3 – FS Links (Fresnel Zones Must Clear the Clutter Field)

However, the Fresnel zone is just the beginning of the path clearance process for links that I am responsible for engineering. Good engineering practice also includes trying to ensure that there is no obstruction in most, if not all, of the 3-dB beamwidth out to several miles from either end of the link. It would be poor engineering practice to have an obstruction in this location, even without the RLAN device.

In urban areas, especially between buildings for a link path, it may be impossible in some situations to have the requisite clearance zone. As I show in calculations in Section 5, for RLANs more than 2 miles from the FS receiver, the carrier-to-interference ratio of the FS link will be at least 49 dB above the RLAN signal level for a 10-mile FS path. If the FS path length is less, then the difference will be even greater, thus providing even greater protection from the RLAN signal from a C/I perspective.

The notion that a good FS engineer will clear most or all of the 3-dB beamwidth as opposed to just the Fresnel zone has important consequences for RLANs because while the FZ may be relatively small, the 3-dB beamwidth is substantially larger. Whereas the 3-dB beamwidth of an FS antenna widens solely based on the main lobe angle and is frequency independent, the Fresnel zone radius is solely a function of distance and frequency. Putting these two ideas together, we can see that for a typical 1.8-degree antenna, the beam widens more quickly than the FZ. For example, at 15 kilometers a 1.8° antenna has a 3-dB beamwidth of 471 meters whereas the Fresnel zone is 26 meters.

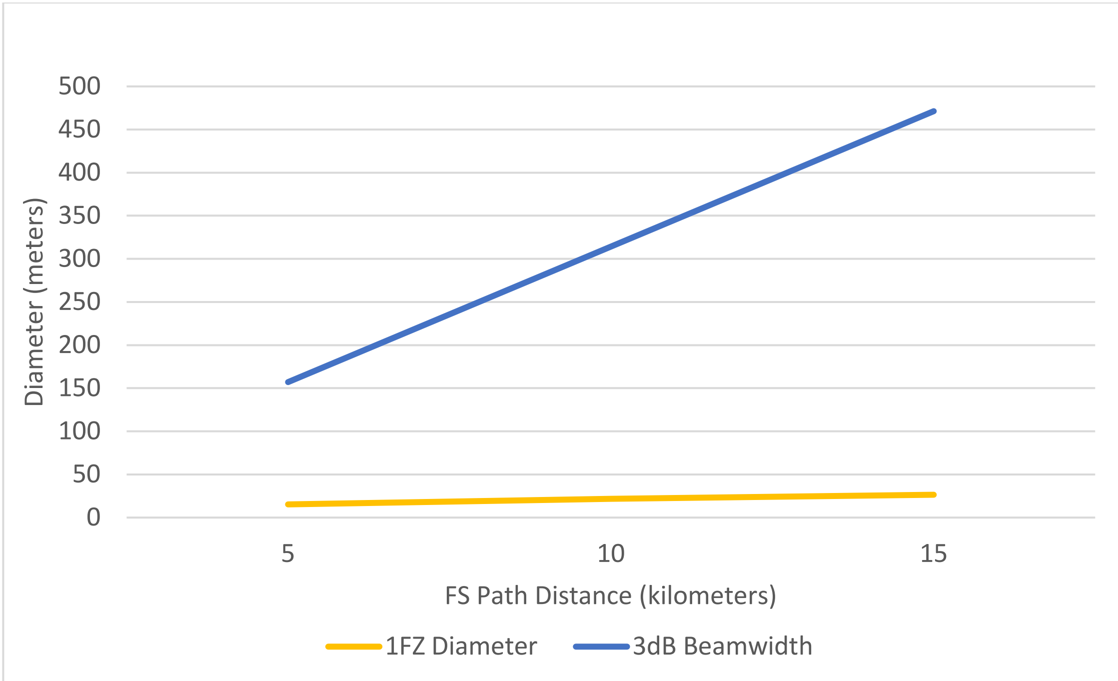

Figure 4– Path Clearance Area for 3-dB Beamwidth vs. Fresnel zone

To shoot a microwave path between buildings down the middle of a street in an urban area is a risky thing to do in my experience, as another building could be built and block the signal in the future unless the street is straight and there is no chance that other obstructions could be made to block the path. It has been argued by others, and I have myself experienced, the erection of a new high-rise building in a path that was determined to be clear when the link was engineered. However, it is worth noting that such buildings must comply with current building codes and therefore will almost always be thermally efficient. Buildings being constructed over the last decade or more are energy efficient and microwave radio signals are substantially attenuated by the low-e glass that is now standard in the construction of new structures. Depending on the exact geometry and height of the building and FS path in such a situation, it may be necessary to re-site the FS path altogether (regardless of RLANs).

Finally, in looking at future microwave systems in urban areas, based on my experience, they will probably not be in the 6 GHz band for several reasons. First, it is increasingly difficult to coordinate such links, especially from 5925 – 6425 MHz. Second, most urban areas have fiber optic cables running to most buildings, and that has replaced the need for microwave as a means to get data into a building.

In designing new systems, most new systems I work on are being built on 11 GHz and higher frequencies, especially in urban areas. The 6 GHz systems are being used mainly in rural areas and where long hops of 10 miles or more per hop are required. To my knowledge, almost all new classes that are teaching radio microwave system design are recommending that engineers not use 6 GHz for urban areas.

5. FACTORS THAT REDUCE RLAN ENERGY RECEIVED BY AN FS RECEIVER

The RLAN devices located in single or two-story buildings will be in the clutter field well below the FS antennas, whether the antennas are mounted on a tower or a building. The RLAN access points that would concern me as an FS engineer for FS receiver interference will be in buildings over 6 stories tall (above the clutter field), and then only those within the main lobe path of the FS antenna. Since most existing FS microwave systems have at least 30 to 40 dB fade margin, the only interference that could affect these FS station receivers would be during extreme signal fade conditions.

This will be a very minute number of units, even if millions of units were in general use. The factors that will make even these small number of access points less likely to be a problem are detailed in this section. These items demonstrate that the RLAN access points can share these channels with FS systems in urban areas with no harmful interference.

- The building exit loss will reduce the signal strength of the RLAN transmitter, and if it is new construction designed for energy efficiency, the possibility of interfering signal will be even lower. Typical values of 20 dB have been cited in the record for traditional buildings[2] and 30 dB for thermally efficient buildings.[3]
- The occupied bandwidth of the FS signals is typically below that of the RLAN station, therefore the entire spectrum of a licensed system will not see all of the energy of the RLAN station. In the common case of a 30 MHz FS receiver fully captured within an 80 MHz RLAN channel, the typical strength of the spread spectrum signal will be 4.25 dB below the aggregate power of the RLAN transmitter.
- FS microwave systems use either vertical or horizontal polarization, as compared with variable polarization from RLAN devices based on their particular geometry. Polarization mismatch loss has been estimated at 3 dB[4].
- The duty cycle of the RLAN transmissions will be very short, and the interference will be minimal.

There are two ways to express interference ratios when looking at interference to a receiver, whether it is a microwave system, land mobile radio system, cellular radio system, or broadcast receiver.

- The first method is to look at the interference ratio relative to the minimum receiver sensitivity threshold (or "T/I"). This will allow the operator of the receiver to see what impact an interfering signal may have at the point where the receiver threshold can first detect the main signal that is the intended for reception.

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[2] NTIA, *Report 95-325: Building Penetration Measurements From Low-Height Base Stations At 912, 1920, and 5990 MHz*, U.S. Department of Commerce (Sept. 1995).

[3] *See Unlicensed Use of the 6 GHz Band, Expanding Flexible Use in Mid-Band Spectrum Between 3.7 and 24 GHz*, Notice of Proposed Rulemaking, FCC No. 18-147, ET Docket No. 18-295 at ¶ 70 (Oct. 24, 2018).

[4] RKF Study at 28.

- The second method is to see how much signal an interfering radio transmitter will have compared to the primary signal that is intended to be coming into the receiver under normal operating conditions (or "C/I").

In the second case, the interference only affects the primary signal when the received signal drops relative to the interference such that it affects the design objective of the link. In a microwave system designed for 99.9999% reliability, this will be under 32 seconds of outage in a year.

Since all microwave systems are designed to accept a certain reduction in the amplitude of the received signal, a minimum 30 dB to 40 dB fade margin is designed into every microwave signal path. As we will see in the calculations below, it can be significantly more than this in many cases (especially urban public safety links which are generally shorter and confined to the jurisdiction they serve). On a C/I basis – which is the method that FS engineers ultimately use to predict link performance - the FS signal will swamp out any interfering RLAN signal in virtually every case. This is the appropriate method to use to assess the impact of low power indoor RLAN devices.

In the following four scenarios, I will demonstrate the ratio between the normal FS receive level and the RLAN signal level on systems where the RLAN signal is within the 3 dB beamwidth of the FS signal in a hypothetical building that is at various distances between the FS transmitter and the FS receiver at the same height of the FS receiver. I will also vary the length of the FS path. Note that all four of these scenarios involve an RLAN in the boresight within 3 miles of an FS receiver, which would never occur on a link for which I am responsible because I clear the path to at least that distance.

In addition, if the RLAN is in a green energy building which generally must be the case to be in the path of an elevated FS link, the ratio will be an additional 10 dB of isolation (for a total of 30 dB) due to the egress of the RLAN signal being reduced by the low e glass and the added energy efficient insulation of the building.

As stated above, there will be an additional 4.25 dB less signal on any given frequency because the bandwidth of the FS signal is much smaller relative to the wider bandwidth of the RLAN (80 MHz for the RLAN as opposed to 30 MHz for FS).

As will be shown, even when the RLAN is within the main beamwidth of the FS receiver antenna and is at an impossibly close distance of 0.2 miles on a 20-mile FS link, the main FS signal C/I level is over 35 dB.

The examples below are based on the following assumptions:

1 – FS path is 6 miles and RLAN path is 0.5 miles.

2 - FS path is 10 miles and RLAN path is 1.0 miles.

3 - FS path is 4 miles and RLAN path is 0.2 miles.

4 - FS path is 20 miles and RLAN path is 0.2 miles.

Scenario #1 – Short FS path with Near-field RLAN

Let us begin with a short path – typical of urban FS links – of 6 miles. In this example, a co-channel RLAN device is transmitting at a worst-case EIRP of 30 dBm. We will use the common 38 dBi minimum gain for the FS antennas on each end, and 3 dB polarization loss. In this example, the FS link has a positive C/I level of 53.6 dB. Note that the Fresnel zone for the FZ link is 21 meters across, whereas the 3 dB beamwidth at the RLAN is just 25 meters. Therefore, this building must obstruct more than 60% of the FZ and no experienced FS engineer would allow it to be built. If such a building were erected at some point after the link was installed, there would be no choice but to relocate the entire FS link regardless of RLANs.

MAIN FS SIGNAL AT RECEIVER

FREQUENCY	6000	MHZ
DISTANCE =	6	MILES
ATTENUATION	127.726	DB

TX POWER	1	WATTS
TX =	30	DBM
ANT GAIN =	76	DB
COAX LOSS	0	DB
ATTENUATION	-127.726	DB
SIGNAL	-21.726	DBM
POLARITY LOSS		DB
BUILDING LOSS		DB
GREEN BLDG		DB

RLAN SIGNAL AT FS RECEIVER

FREQUENCY	6000	MHZ
DISTANCE =	0.5	MILES
ATTENUATION	106.142	DB

TX POWER	1	WATTS
TX =	30	DBM
ANT GAIN =	38	DB
COAX LOSS	0	DB
ATTENUATION	-106.142	DB
SIGNAL	-38.142	DBM
POLARITY LOSS	-3	DB
BUILDING LOSS	-20	DB
GREEN BLDG	-10	DB
BW MISMATCH	-4.25	DB
CARRIER TO INTERFERENCE RATIO	53.666	DB

Scenario #2 – Medium length FS path with Near-field RLAN

In this example, we consider a slightly longer 10-mile FS link which is common in both urban and suburban environments. The co-channel RLAN is placed at 1 mile. The FS link has a positive C/I level of 55.25 dB. Here again, the scenario is extremely unlikely. The FZ for a 10-mile path is 27 meters across, whereas the 3 dB beamwidth at 1 mile is 50 meters across. While it is conceivable that an FS link could pass immediately next to such a building, the risk of destructive multipath interference is very high.

MAIN FS SIGNAL AT RECEIVER

FREQUENCY	6000	MHZ
DISTANCE =	10	MILES
ATTENUATION	132.163	DB

TX POWER	1	WATTS
TX =	30	DBM
ANT GAIN =	76	DB
COAX LOSS	0	DB
ATTENUATION	-132.163	DB
SIGNAL	-26.163	DBM
POLARITY LOSS		DB
BUILDING LOSS		DB
GREEN BLDG		DB

RLAN SIGNAL AT FS RECEIVER

FREQUENCY	6000	MHZ
DISTANCE =	1	MILES
ATTENUATION	112.163	DB

TX POWER	1	WATTS
TX =	30	DBM
ANT GAIN =	38	DB
COAX LOSS	0	DB
ATTENUATION	-112.163	DB
SIGNAL	-44.163	DBM
POLARITY LOSS	-3	DB
BUILDING LOSS	-20	DB
GREEN BLDG	-10	DB
BW MISMATCH	-4.25	DB
CARRIER TO INTERFERENCE RATIO	55.250	DB

Scenario #3 – Very short FS path with Very near-field RLAN

Here we model an RLAN at an impossibly close distance of 0.2 miles that an FS engineer has negligently allowed to fully intrude into the FZ. In this case, the FZ diameter for the FS path is 17 meters whereas the 3 dB beamwidth is 10 meters at the RLAN. Such an FS link could not work, but the geometry is instructive for evaluating C/I. I calculate a C/I in favor of the FS of 49.2 dB.

MAIN FS SIGNAL AT RECEIVER			RLAN SIGNAL AT FS RECEIVER		
FREQUENCY	6000	MHZ	FREQUENCY	6000	MHZ
DISTANCE =	4	MILES	DISTANCE =	0.2	MILES
ATTENUATION	124.204	DB	ATTENUATION	98.184	DB
TX POWER	1	WATTS	TX POWER	1	WATTS
TX =	30	DBM	TX =	30	DBM
ANT GAIN =	76	DB	ANT GAIN =	38	DB
COAX LOSS	0	DB	COAX LOSS	0	DB
ATTENUATION	-124.204	DB	ATTENUATION	-98.184	DB
SIGNAL	-18.204	DBM	SIGNAL	-30.184	DBM
POLARITY LOSS		DB	POLARITY LOSS	-3	DB
BUILDING LOSS		DB	BUILDING LOSS	-20	DB
GREEN BLDG		DB	GREEN BLDG	-10	DB
			BW MISMATCH	-4.25	DB
	CARRIER TO INTERFERENCE RATIO			49.229	DB

Scenario #4 – Long FS path with Very near-field RLAN

The effect of very close RLANs is of great concern to FS engineers, due to the weaker FS received power as against a strong interferer. This example shows such concerns to be unfounded. A 20-mile FS link with a 39-meter Fresnel zone is intruded by the same RLAN at 0.2 miles (where the 3 dB beamwidth is just 10 meters) in a building that is thus completely obstructing the FS path and could not exist in real life. Nevertheless, the calculation yields a positive C/I of 35.25 dB.

MAIN FS SIGNAL AT RECEIVER

FREQUENCY	6000	MHZ
DISTANCE =	20	MILES
ATTENUATION	138.184	DB

TX POWER	1	WATTS
TX =	30	DBM
ANT GAIN =	76	DB
COAX LOSS	0	DB
ATTENUATION	-138.184	DB
SIGNAL	-32.184	DBM
POLARITY LOSS		DB
BUILDING LOSS		DB
GREEN BLDG		DB

RLAN SIGNAL AT FS RECEIVER

FREQUENCY	6000	MHZ
DISTANCE =	0.2	MILES
ATTENUATION	98.184	DB

TX POWER	1	WATTS
TX =	30	DBM
ANT GAIN =	38	DB
COAX LOSS	0	DB
ATTENUATION	-98.184	DB
SIGNAL	-30.184	DBM
POLARITY LOSS	-3	DB
BUILDING LOSS	-20	DB
GREEN BLDG	-10	DB
BW MISMATCH	-4.25	DB
CARRIER TO INTERFERENCE RATIO	35.250	DB

The previous examples highlight the reason why FS engineers must generally ensure that the 3 dB beamwidth of an FS receiver is clear to a significant distance. FS links in urban areas are shorter paths, and rarely have large bodies of water below the path, so there is minimal fading of the primary FS microwave path. In these examples, the RLAN signal level is so far below the main carrier channel that the C/I level is at least 35 dB and up to 55 dB.

The time domain is another important factor that is not clear from a simple link budget interference analysis. RLAN data bursts will be in the 0.1 to 8 millisecond range, and even if such bursts were of sufficiently high energy to affect an FS link, the forward error correction and adaptive modulation that is part of all current technology digital microwave systems on the market will just see this as a quick fade and will not even adapt down for the main data stream of that system.

6. ROBUSTNESS OF MODERN FIXED SERVICE RADIOS

The microwave links of today use multiple techniques in order to be more reliable than past years. In my experience, technological advances in radio design, filtering, and error correction, coupled with tried and proven path diversity engineering methods, have made deep fades-based outages largely a thing of the past. This section will detail some of these advances and design methods that FS licensees use to prevent outages.

a. Adaptive Modulation & Coding (AMC)

To my knowledge, virtually all of the FS radio technology in use today has adaptive modulation and coding on the FS links. This means that the data rate slows down to the next lowest modulation when the carrier signal fades or the noise floor rises. With AMC, paths that used to be broken and drop out completely continue to function during these amplitude valleys in the signal levels. I have not deployed a link without AMC-capable equipment in many years.

b. Forward Error Correction (FEC)

To my knowledge, most modern FS links now employ digital modulation techniques. With that advancement, the use of forward error correction allows the links to keep operating reliably during fades or interference bursts. All of the links I deploy are FEC capable.

c. Space, Frequency & Polarization Diversity

A microwave system that is designed for critical 24/7 operation will use redundant paths. These can be either space diversity, where two separate antennas at different heights are used for both the transmitting and receiving ends of a link, or frequency diversity, where different frequency bands are used to trick the fades in signal to occur at different times for the different frequencies.

Some systems use the same frequencies in their diversity systems, but use a different polarity as the backup antenna system. Again, this is to ensure that the multipath fading in one plane is not affected the same in another plane.

FS links are also designed to account for the fact that, even with the most robust protections, FS links will, in rare events, lose small amounts of data. They are designed to detect these events and rapidly recover.

Another type of fading that occurs in microwave systems is that part of the licensed spectrum takes a fade, but other parts of the same channel do not have this notch in the signal at the same time. This distortion of the overall signal used to be another problem in digital modulation schemes, but the manufacturers have corrected it via automatic gain control (AGC) by equalizing the gain within different subcarriers of the same channel to keep the received level close to constant, despite these signal aberrations.

The combination of the state-of-the-art techniques to minimize the effects of path fades has made the deep fade outages in microwave systems a thing of the past. In fact, radio manufacturers make a point of promoting the "fade resistance" of their equipment. This has increased the reliability of the FS station links to the point where most systems do not suffer outages any more.

7. <u>ACCURACY OF THE FCC UNIVERSAL LICENSING SYSTEM (ULS)</u>

All licensed 6 GHz radio systems can be found in the ULS database. The information includes the location of the towers or other mounting structures, the radio antenna make and model, the antenna height, and the direction where the antennas are pointed. ULS includes a wealth of other data as well which collectively is suitable for performing frequency coordination for the Fixed Service, the Broadcast Auxiliary Service, and other licensed services.

A. Sources of location error

Since the oldest systems were licensed before GPS was available or widely used, the location information of some such systems is known by its owners to be incorrect. In my experience, such errors have propagated down through the years for two reasons. First is the cost to re-file the license with updated information. While nominal individually, this could add up for a license holder with many such links. Of course, all FS links face a mandatory decennial license renewal requirement where a fee must be paid anyway. However, the second reason incorrect locations remain frozen in time is that under current rules, a significant location change triggers a mandatory re-coordination requirement.[5] Obviously, coordinated links that have been working for decades are self-evidently properly coordinated.

Introducing RLANs into the band changes this calculus. Because the RLANs need to know the locations of every transmitter and receiver in the 6 GHz band for Automated Frequency Coordination (AFC) systems to operate, FS licensees should be incentivized to ensure their information is correct. To that end, there should be an amnesty or grandfathering program where licensees may revise their exact locations and heights to be very accurate on their current licenses without a re-coordination requirement so long as the link has been in operation several years. There should also be a moratorium on filing fees.

B. Dealing with Licensees with incomplete or inaccurate ULS data

The FCC can easily identify licensees with incomplete or missing data for the AFC to function properly. The FCC should also notify all licensees that missing or wrong information will seriously impact them on the protection that they expect by having coordinated licensed channels.

There should be a strong incentive to correct incomplete registrations. Inaccurate and incomplete registration information presents problems both for unlicensed RLAN operations using an AFC as well as for other FS licensees.

C. Uses of the 6 GHz band

Since most new microwave systems now use 11 GHz and above for the operation of broadband and narrowband connectivity, the 6 GHz band should be reserved for long distance communications. Most engineering text books and seminars are stating that 6 GHz should be reserved for long paths and areas other than urban locations.[6] 6 GHz is good for long paths because they are not affected by rain or other types of precipitation. In urban areas, 11 GHz and higher is the preferred method of providing wideband connectivity for companies, carriers, utilities, and governmental agencies.

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5 *See* 47 C.F.R. § 101.103(d)(1) (requiring coordination prior "filing an application for regular authorization, or a major amendment to a pending application, or any major modification to a license").

6 For example, Tonex does not even offer training on 6 GHz system planning in their microwave training classes. Tonex, *Microwave Training: Microwave Radio Link Planning and Frequency*, tonex.com (last accessed Feb. 15, 2019), https://www.tonex.com/training-courses/microwave/.

8. CONCLUSION

The biggest concerns with the integration of the Fixed Service 6 GHz microwave systems and RLAN devices are described by FS licensees as residences and businesses expected to use these RLAN devices in high-rise buildings in urban areas.

This report has focused on RLAN devices located on higher floors of buildings above the clutter line that are in the path of an existing 6 GHz FS beam pattern. Any building that is within the 3 dB beamwidth of the FS path would fall into this category.

The analyses shown in Section 5 above show that in every path analyzed, the main FS path signal level at the FS receiving antenna is at least 35 dB and up to 55 dB above the RLAN energy level. We have explored the fact that many links, especially in urban areas, are comparatively short at less than 20 miles, with a corresponding increase in available fade margin. While theoretical MCL calculations can be made to show otherwise, in practice in the real world, indoor low power RLAN units should virtually never run into a situation where the RLAN interferes with an FS station because they have a minimal probability of being in the beam to begin with due to standard engineering best practices.

Because modern digital FS systems operate with a received signal that experiences much less fading than the older systems, the use of C/I analysis with respect to RLAN interference is not only valid but the appropriate approach for low power indoor RLANs in buildings taller than about 6 stories. In my experience, FS link design always engineers for path clearance of the FZ above the clutter line, which is typically about 70 feet or the height of a six-story building.

In addition, the digital technology with forward error correction, very fast automatic gain control circuits, frequency equalization circuits, adaptive modulation control, and fade margin mitigation designed into the systems has made these new systems largely immune from fade margin outages.

Our grandfather's microwave systems were all analog, and today, they are either sitting in a museum or have been melted down for the base metals. The manufacturers all brag about the "no-fade" models that they sell, and the extremely long range of the new systems. Finally, the engineers have come to realize that 6 GHz does not belong in the urban environment, and their books and instructors are telling the new engineers to use the higher frequencies in the urban areas.

In my professional opinion, all of these items combined demonstrate how low power indoor RLAN devices and the FS 6 GHz stations can safely co-exist and not interfere with each other.

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